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Part 2.—Geological notes on the route traversed by the Yarkand Embassy from Shah-i-Dula to Yarkhand and Kashgar. On the occurrence of jade in the Karakas valley, on the southern borders of Turkistan. Notes from the Eastern Himalaya. Petroleum in Assam. Coal in the Garo hills. On the discovery of a new locality for copper in the Narbada valley. Potash-salt from East India. On the geology of the neighbourhood of Mari hill station in the Punjab.

Part 3.—Geological observations made on a visit to the Chaderkul, Thian Shan range. On the former extension of glaciers within the Kangra district. On the building and ornamental stones of India. Second note on the materials for iron manufacture in the Raniganj coal-field. Manganese ore in the Wardha coal-field.

Part 4.—The auriferous rocks of the Dhambal hills, Dharwar district. Remarks on certain considerations adduced by Falconer in support of the antiquity of the human race in India. Geological notes made on a visit to the coal recently discovered in the country of the Luni Pathans, south-east corner of Afghanistan. Note on the progress of geological investigation in the Godavari district, Madras Presidency. Notes upon the subsidiary materials for artificial fuel.

Vol. VIII, 1875.

Part 1.—Annual report for 1874. The Altum-Artush considered from a geological point of view. On the evidences of 'ground-ice' in tropical India, during the Talchir period. Trials of Raniganj fire-bricks.

*Part 2 (out of print).**—On the gold-fields of south-east Wynaad, Madras Presidency. Geological notes on the Khareean hills in the Upper Punjab. On water-bearing strata of the Surat district. Sketch of the geology of Scindia's territories.

Part 3.—The Shahpur coal-field, with notice of coal explorations in the Narbada region. Note on coal recently found near Moflong, Khasia Hills.

Part 4.—Note on the geology of Nepal. The Raigarh and Hingir coal-fields.

Vol. IX, 1876.

*Part 1 (out of print).**—Annual report for 1875. On the geology of Sind.

Part 2.—The retirement of Dr. Oldham. On the age of some fossil floras in India. Description of a cranium of Stegodon Ganesa, with notes on the sub-genus and allied forms. Note upon the Sub-Himalayan series in the Jamu (Jummoo) Hills.

Part 3.—On the age of some fossil floras in India. On the geological age of certain groups comprised in the Gondwana series of India, and on the evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. On the relations of the fossiliferous strata at Maleri and Kota, near Sironcha, C. P. On the fossil mammalian faunæ of India and Burma.

Part 4.—On the age of some fossil floras in India. On the osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Occurrence of Plesiosaurus in India. On the geology of the Pir Panjal and neighbouring districts.

Vol. X, 1877.

Part 1.—Annual report for 1876. Geological notes on the Great Indian Desert between Sind and Rajputana. On the occurrence of the cretaceous genus Omphalia near Nameho lake, Tibet, about 75 miles north of Lhassa. On Estheria in the Gondwana formation. Notices of new and other vertebrata from Indian tertiary and secondary rocks. Description of a new Emydine from the upper tertiaries of the Northern Punjab. Observations on underground temperature.

Part 2.—On the rocks of the Lower Godavari. On the 'Atgarh Sandstones' near Cuttack. On fossil floras in India. Notices of new or rare mammals from the Siwaliks. On the Arvali series in North-eastern Rajputana. Borings for coal in India. On the geology of India.

Part 3.—On the tertiary zone and underlying rocks in the North-west Punjab. On fossil floras in India. On the occurrence of erratics in the Potwar. On recent coal explorations in the Darjiling district. Limestones in the neighbourhood of Barakar. On some forms of blowing-machine used by the smiths of Upper Assam. Analyses of Raniganj coals.

Part 4.—On the Geology of the Mahanadi basin and its vicinity. On the diamonds, gold, and lead ores of the Sambalpur district. Note on 'Eryon Comp. Barrovensis,' McCoy, from the Sripermatur group near Madras. On fossil floras in India. The Blaini group and the 'Central Gneiss' in the Simla Himalayas. Remarks on some statements in Mr. Wynne's paper on the tertiaries of the North-west Punjab. Note on the genera Chœromeryx and Rhagatherium.

Vol. XI, 1878.

Part 1.—Annual report for 1877. On the geology of the Upper Godavari basin, between the river Wardha and the Godavari, near the civil station of Sironcha. On the geology of Kashmir, Kishtwar, and Pangi. Notices of Siwalik mammals. The palæontological relations of the Gondwana system. On 'Remarks, &c., by Mr. Theobald upon erratics in the Punjab.'

Part 2.—On the Geology of Sind (second notice). On the origin of the Kumaun lakes. On a trip over the Milam Pass, Kumaun. The mud volcanoes of Ramri and Cheduba. On the mineral resources of Ramri, Cheduba, and the adjacent islands.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1899

TO THE 31ST MARCH

1900.

UNDER THE DIRECTION OF

C. L. GRIESBACH, C.I.E., F.G.S.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT, GOVERNMENT PRINTING, INDIA.
1900.

CALCUTTA:
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CONTENTS.

Page.

GEOLOGICAL SURVEY OF INDIA, LIST OF OFFICERS . . ii

PART I.—Head-Quarter Notes 1
- 1. Museum and Laboratory 1
- 2. Palæontological Work 16
- 3. Publications 22
- Personnel 23

PART II.—Field Parties 24
- A. Economic Enquiries 25
  - 1. Gold 25
  - 2. Coal 27
  - 3. Landslip at Darjeeling 27
  - 4. Irrigation 29
- B. Geological Surveys 32
  - 1. Burma 32
  - 2. Madras Presidency 37
  - 3. Central Provinces 40
  - 4. Punjab 41
  - 5. Himalayas 44
  - 6. Sind 49
  - 7. Baluchistan 50

PART III.—*Progress Reports of Officers of the Geological Survey of India for the year 1899-1900* 53

Note on the Auriferous reefs of south and south-east Wainad, by H. H. Hayden, B.A., B.E. 53

Preliminary Report on the auriferous tract in the Wuntho District in Burma, by G. A. Stonier, A.R.S.M., F.G.S. 59

Preliminary Report on the Rampur Coal-field, by G. F. Reader, F.G.S. . 63

Preliminary Report on the Sohagpur Coal-field, by G. F. Reader, F. G. S. 69

Preliminary Report on the Geology of the Northern Shan States, by T. D. LaTouche, B.A.. 74

Notes on the Geology of the country along the Mandalay-Kunlon Ferry Railway route, Upper Burma, by P. N. Dutta, B. Sc., F.G.S. 96

Report on a Geological reconnaissance in parts of the Southern Shan States and Karenni, by C. S. Middlemiss, B.A. . . . 122

Preliminary Report on the Geology of the Ganjam District, by F. H. Smith, A.R.C.S. 153

A Geological Sketch of the Central portion of Jeypore Zemindari, Vizagapatam District, by T. L. Walker, M.A., Ph. D.. . . 166

Notes on the Relationship between the Productus limestone and the Ceratite formation of the Salt Range by F. Noetling, Ph.D., F.G.S. 176

Progress report on the Survey of Spiti and adjoining areas, by H. H. Hayden, B.A., B.E. 184

Page.
Stratigraphical notes on the Mesozoic rocks of Spiti, by Dr. A. von Krafft . 199
Abstract of Report on the Geological structure of the sites proposed for the Bhavani dam, by T. H. Holland, A.R.C.S., F.G.S. . 230
APPENDIX I.—List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, from the 1st April 1899 to the 31st March 1900 234
Additions to Library 237
APPENDIX II.—The Inspector of Mines in India 258

GEOLOGICAL SURVEY OF INDIA.

DIRECTOR.

C. L. GRIESBACH, C.I.E., F.G.S., on tour to Madras, 7th June to 4th July 1899; on tour to Central Provinces, Rajputana, and Gujarat, 5th February to 19th March 1900.

SUPERINTENDENTS.

1. R. D. OLDHAM, A.R.S.M., F.G.S., on furlough from 11th July 1899.
2. TOM D. LATOUCHE, B.A., privilege leave for 3 months, availed of from 19th April 1900.
3. C. S. MIDDLEMISS, B.A., also Curator from 1st to 30th April 1899, *vice* Dr. T. L. Walker.

DEPUTY SUPERINTENDENTS.

1. P. N. BOSE, B. Sc. (London), F.G.S., on privilege leave from the 15th May to the 29th June 1899.
2. T. H. HOLLAND, A.R.C.S., F.G.S., also Curator from 1st May 1899, *vice* Mr. Middlemiss, and Officiating Superintendent from 6th July 1899, *vice* Mr. R. D. Oldham.
3. P. N. DATTA, B. Sc. (London), F.G.S.
4. F. H. SMITH, A.R.C.S.

ASSISTANT SUPERINTENDENTS.

1. H. H. HAYDEN, B.A., B.E., also Officiating Deputy Superintendent from 6th July 1899, *vice* Mr. T. H. Holland.
2. E. VREDENBURG, B.L., B. Sc. (Paris), A.R.C.S.
3. T. L. WALKER, M.A. (Kingston), Ph. D. (Leipzig), confirmed in the grade from 8th May 1899.
4. A. KRAFFT von Dellmensingen, Ph. D. (Vienna). Passed the examination in Hindustani by the Lower Standard on 1st May 1899.

PALÆONTOLOGIST.

FRITZ NOETLING, Ph.D. (Berlin), F.G.S.

SPECIALISTS.

1. G. A. STONIER, A.R.S.M., F.G.S., appointed by the Secretary of State for India as Specialist in Mining and Metallurgy for 5 years, and joined this Department on 4th October 1899.
2. G. F. READER, F.G.S., appointed by the Secretary of State for India as Coal Mining Specialist for 5 years. Arrived in Calcutta on 31st October 1899, and joined this Department on 1st November 1899.
3. F. H. HATCH, PH. D., A.M.I.C.E., appointed by the Secretary of State for India as Gold Mining Expert for one year. Arrived in Bombay 31st March 1900 and assumed his duties from that date.

SUB-ASSISTANTS.

1. HIRA LAL, on furlough from 1st April to 4th September 1899.
2. KISHEN SING, on privilege leave from 23rd August to 7th October 1899.

ARTIST.

H. B. W. GARRICK.

REGISTRAR.

A. E. MACA. AUDSLEY, appointed Registrar in this Department, from 18th May 1899.

MUSEUM ASSISTANT.

T. R. BLYTH, deputed to Paris in charge of Geological Collections. Left Calcutta by B. I. S. N. Co.'s S.S. *Goorkha*, on 30th January 1900.

INSPECTOR OF MINES IN INDIA.

JAMES GRUNDY.

GENERAL REPORT

ON THE WORK CARRIED ON BY THE

GEOLOGICAL SURVEY OF INDIA

FOR THE PERIOD FROM THE 1ST APRIL

1899

TO THE 31ST MARCH

1900.

PART I.—HEAD-QUARTER NOTES.

Director's Tours.

During the twelve months under review, I made the following tours:—

(1) From the 7th June to the 5th July 1899 to the Madras Presidency to arrange for the survey work to be carried on during the field season 1899-1900.

(2) From the 5th February to the 20th March 1900 to the Central Provinces, Gujerat, Rajputana, and Sind in connection with an inquiry into the possibility of obtaining water by Artesian borings.

1.—MUSEUM AND LABORATORY.

Curator.

Mr. T. H. Holland took charge of the office of Curator on the 1st May 1899, relieving Mr. C. S. Middlemiss. Mr. Holland reports on his duties during the past year as follows:—

Rearrangement of specimens in the show-cases.

With the limited amount of space available in the Museum it has been possible in the classified collection of minerals to exhibit only representative specimens of each type, the cases being altogether too crowded to represent the known localities for each species. But in connection with the collection of economic minerals it has always been the aim of the department to make it fully representative of our knowledge concerning the occurrences in India of valuable minerals. With the numerous additions which have been made of late years it was found that the accommodation originally provided was rapidly becoming insufficient, and accordingly arrangements have now been made for extending the collection along the northern recess cases previously occupied by a set of foreign rock specimens. The classification originally adopted by Mr. Mallet has been retained, and with the additional accommodation the metalliferous ores, and minerals which are of value because of the base they contain, occupy the northern recesses, whilst the non-metallic products and materials, like mica and corundum, which are of value on account of their special physical properties, are exhibited in the southern recess cases. The cases containing these minerals have been cleaned throughout and the specimens completely labelled.

The collection of Indian rock-specimens occupying cases Nos. 37 to 80 in the centre of the gallery have now been arranged in the stratigraphical order adopted in the new edition of the Manual of Indian Geology. On account of petrological studies which have been made since the issue of the Manual, we are now able to indicate amongst the great complex of crystalline rocks certain formations which, though foliated in conformity with the gneisses around, are regarded as normal, though very ancient, intrusive, igneous rocks. The removal of these from the ordinary gneiss groups does not disturb the classification adopted by the older workers, for the residue of the crystalline schists, and, like somewhat similar formations found in other countries, they are retained side-by-side with the two main groups of schists, as they are also very old, and, in default of evidence to the contrary, may be grouped with the Archæan. The following are amongst such groups of igneous rocks which have been identified:—

(1) The elæolite-syenites, augite-syenites and associated corundiferous felspar rocks of the Coimbatore district.

(2) The ægirine-granites and augite-syenites of Salem district.

(3) Various gneissoid granites, like the so-called "dome gneiss" of Behar, the central granite of Coorg, etc.

(4) Pyroxene-granulites and granulites distinguished under the name "charnockite series."

(5) Anorthosites of Bengal and norites of Coorg.

(6) Various ancient basic pyroxenic dykes and lenticular masses partially or wholly changed to epidiorites.

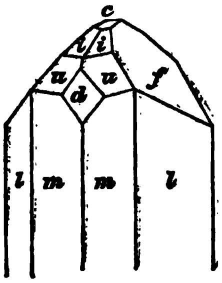
In conformity with the system adopted in the Manual the various Peninsular intrusives in the gneisses, which are young enough to have escaped foliation, are exhibited near the ancient rocks which they traverse. Of these, one case is devoted to the display of the mica-bearing pegmatites, and two others to the exhibition of various types of felsites, porphyries, basic dykes and peridotites, which are found as dykes and other intrusive masses in the gneisses.

Selections from the collection of foreign-rock-specimens have been arranged and labelled in 14 cases in the north-west room as illustrations of petrographical geology, the series of illustrations of physical geology being reserved to the remaining 10 cases in the same room.

The class, order and generic names have been completely renewed throughout the gallery of tertiary fossil vertebrates, and considerable progress made towards renovating the labels throughout the Museum.

Besides the collections made during the previous field season by the officers of the department, a number of interesting additions have been made during the year. Mr. H. H. Hayden obtained a series of specimens and photographs illustrating the manufacture of borax in Ladakh.

Amongst a series of river gravels from the Katha district sent by the Burma Government, several colourless topaz crystals were detected amongst other gem-stones. The discovery is of interest as the first-recorded occurrence of the mineral topaz in India or Burma. Amongst the fragments one was found with faces sufficiently well preserved for determination with the reflecting goniometer. The following forms, represented in the wood-cut, were found :—



m	(110)	prisms.
l	(120)	
f	(021)	brachydome.
i	(223)	pyramids.
u	(111)	
d	(201)	macrodome.
c	(001)	basal plane.

From Burma also we have received specimens of antimonial tetrahedrite, tin-stone and wolfram obtained in the Shan States, and pebbles of pure rutile obtained by Mr. C. M. P. Wright in the Katha district.

Mr. R. D. Oldham has presented the Department with an interesting collection of crystalline rocks collected in Ceylon whilst on furlough. They include, besides pyroxene-granulites, granulites and gneisses similar to those known in the southern districts of the Madras Presidency, specimens showing veins of graphite in a quartz-felspar rock, the moonstone in its matrix of pegmatite, and cipolin with a blue apatite (moroxite) similar to that occurring in the ruby-bearing limestone of Burma.

Meteorites.

A few additions have been made to the collection of meteorites by exchange; but the most interesting is a new meteoric iron found near Kodaikanal on the Palni Hills, Madura district, and acquired by purchase through the help of Mr. C. Michie Smith, Director of the Madras Observatories. This meteorite weighed about 35 lbs. when found, and was covered with a coat of rust due to its having, in all probability, been exposed for some time to the weather. There is no record of its fall, but a large meteor was seen eight years before to burst over the Pillar Rocks near Kodaikanal, and it is not unlikely that this "iron" fell at the time.

It is found to be composed almost entirely of nickeliferous iron, with included irregular mineral masses, measuring sometimes 10 mm. across. Crystal structures—imperfect Widmanstätten figures—are developed by etching the polished surface of the iron with dilute acid; but beyond these tests, which satisfactorily establish the meteoric origin of this iron, the specimen has not yet been examined in detail. The surface shows the "thumb-marks" characteristic of the siderites.

A certain amount of interest is attached to this "find" on account of the rarity of Indian meteoric irons. Although stony meteorites have been found in great numbers, only one other iron has been obtained in India, and that was seen to fall near Nidigullum (lat. 18° 41′ 20″; long. 83° 28′ 30″) in the Vizagapatam district on January 23rd, 1870. The Nidigullum meteorite[1] weighed 10 lbs. only, so the Kodaikanal meteorite, beside being only the second Indian "iron" recorded, is much the larger of the two.

---

[1] Proc., Asiatic Soc. Beng., 870, p. 64.

Paris Exhibition.

A considerable amount of time during the year was taken up in connection with preparations for the Paris Exhibition to which a collection of specimens, maps and photographs have been sent by this department. On account of the limited space placed at our disposal, selections only have been made from the material available for the purpose. These have been grouped in the gallery as follows:—

(1) A collection of rock specimens from the Peninsula with photographs and drawings of rock-sections, illustrating the chief types of Archæan crystalline schists and the igneous rocks associated with, or intruded into, them.

(2) A collection of minerals of economic value, illustrating the resources in minerals used for ornamental purposes, corundum, mica, graphite and the principal natural compounds of borax, phosphorus, sulphur, strontium, barium, magnesium, aluminium, manganese, iron, titanium, molybdenum, tin, lead, antimony, arsenic, copper, and gold.

(3) A collection of various minerals, mostly presenting characters peculiar to India.

(4) A collection of Gondwana coals.

(5) A collection of striated and facetted boulders.

(6) A collection of specimens, maps and photographs illustrating the geology and resources of the Giridih coalfield as a type of the Gondwana coalfields of Bengal.

(7) A case containing specimens of the flexible sandstone obtained from the Punjab.

(8) A collection of iron-ores and native-made iron and steel, together with specimens of the products of the Barakar Iron Works which are conducted on European lines by the Bengal Iron and Steel Company. Photographs of the works and of Native iron and steel makers.

(9) A collection of specimens showing various forms of laterite kankar and other concretionary rocks.

(10) A collection of rock-salt and associated minerals from the Punjab.

(11) A collection of Burma petroleum and products artificially prepared therefrom by the Burma Oil Company.

(12) A collection of one-foot cubes of building stones and a series of slabs, carved screens and pillars made from rocks used for ornamental and building purposes.

(13) A collection of maps, diagrams and photographs grouped to illustrate certain points in the Geology of—

 (*a*) the Indian Peninsula,
 (*b*) the Himalayan region, and,
 (*c*) the areas lying outside the Peninsula and the Himalayas.

(14) A collection of memoirs and manuals published by the Geological Survey of India and descriptive of the geological results obtained by the Department.

Several valuable specimens were contributed to the collection of exhibits by Mining Companies in India. The following are the principal contributors:—

Bengal Coal Coy., Ld.—Cubes of coal and specimens of coke from the Bengal fields.

East Indian Railway Coy., Ld.—Coal, coke rock-specimens and diagrams of the Giridih coalfield.

Chief Engineer, Central Provinces.—Coal from different seams in the Warora and Umaria collieries.

Hyderabad (Deccan) Coy., Ld.—Coal from the Singareni collieries.

Bengal Iron and Steel Coy., Ld.—Ore, fuel, and limestone used, and various pigs and articles of cast-iron manufactured, in the Barakar Iron-works.

Burma Oil Coy., Ld.—Various petroleums and manufactured by-products.

Messrs. Ambler & Co.—Various slates from the Kharakpur hills.

Mysore Geological Department.—Gneiss slabs and ornamental stones from Mysore State.

Commissioner of Coorg.—Cubes of Watekolli norite.

Visianagram Mining Co.—Various manganese ores from the Kodur mines.

Messrs. F. F. Chrestien & Co.—"Books" of mica and sickle-dressed mica of various colours and grades.

Indian Mica Coy., Ld.—Various micas from the Bendi mines.

Messrs. C. A. Macdonald & Co.—Mica from the Koderma area, Hazaribagh district.

Messrs. Best & Co.—Mica from the Nellore district.

Commissioner of Northern India Salt Revenue.—Salt and associated minerals from different areas in the Punjab.

Madras Government.—Native-made iron and steel from the Salem, Trichinopoli and Malabar districts.

The following donations have been made to the Museum during the past year:—

Donation.	Presented by.
Auriferous quartz with altaite and chalcopyrite .	The Manager, Choukpazat Gold Mining Coy., Ld.
Sheets of muscovite, Tellabodu mica mines, Nellore district.	A. Subha Naidu.
Sheets of muscovite, Biradavole mica mines, Nellore district.	Messrs. Best & Co.
"Potato stone," Bankura district	Raja Sir Sourindro Mohan Tagore, Kt., C.I.E.
Specimens of serpentine and gabbro from stream bed entering Lamia Bay, Great Andaman Island.	Captain A. R. S. Anderson, I.M.S.
Galena from Raksi (23° 59′; 85° 1′), Hazaribagh district.	A. Gow Smith, Esq.
Slice of the Tonganoxie meteoric iron. Weight 140 grammes.	Professor H. A. Ward.
Specimens of mica with inclusions of garnet and apatite, Bendi, Hazaribagh district.	A. Mervyn Smith, Esq.
Specimens of apatite, garnet and "silvery" muscovite near Bendi, Hazaribagh district.	A. Mervyn Smith, Esq.
Specimens of corundum in felspar rock, garnets, twinned crystals of muscovite, microcline, chrysoberyl, blue apatite and graphic granite from the neighbourhood of Padyur and Karutapalaiyam, Coimbatore district.	Captain H. M. Campbell, R.A.
Selenite from near Kharagoda, Rann of Cutch .	H. G. Bulkley, Esq.
Quartz with epidote and cubes of limonite pseudomorphous after pyrite, from the Murbhanja State.	Babu Tinkari Choudhry.
Slab of fuchsite-quartzite from hills near Nemakallu, Bellary district.	Superintendent, Government Museum, Madras.
Rolled pebbles of rutile from Mohynui, Katha district, Burma.	C. M. P. Wright, Esq.

Donation.	Presented by.
Mud pellets which fell during a shower of rain in Daltonganj district, October 1899.	Meteorological Reporter to the Government of Bengal.
Blocks of Magnesite, Chalk Hills, Salem district .	Messrs. Arbuthnot & Co.
Triplite, Singar, Gaya district	H. M. Hannay, Esq.
Elæolite-Syenite from Girnar, Junagar . . .	Colonel J. M. Hunter, C.S.I.
Iron-pyrites from the main coal seam, Kuldiha colliery, Giridih coalfield.	E. Seymour Wood, Esq., F.G.S.
Topaz crystal, from tributary of the Ledaw-chaung, Katha district, Burma.	R. Clarke, Esq.
Specimens of moonstone in its pegmatite matrix; veins and disseminated scales of graphite in granite and quartz; cipolin with moroxite; pyroxene granulite; granulite; biotite gneiss; marble; calciphyre; pyroxenite; biotite rock and biotite sheets from various localities in Ceylon.	R. D. Oldham, Esqre., F. G. S., Geological Survey of India.

List of Assays and Examinations made in the Laboratory during the past year.

<table>
<tr><th>Substance and locality.</th><th>Sender.</th><th>Results of examination.</th></tr>
<tr><td>A specimen from the Sirohi State for determination.</td><td>Captain F T. C. Hughes, I.S.C., Erinpura.</td><td>*Carbonaceous shale.*
Composition :—
<table>
<tr><td>Moisture . .</td><td>0·56</td></tr>
<tr><td>Volatile matter .</td><td>2·96</td></tr>
<tr><td>Fixed carbon .</td><td>8·94</td></tr>
<tr><td>Ash . . .</td><td>87·54</td></tr>
<tr><td></td><td>100·00</td></tr>
</table>
Does not coke. Ash, light-brown.</td></tr>
<tr><td>Three specimens from the Mahanadi River, Bhatgaon, Bilaspur district.</td><td>F. H. Smith, Esq., Deputy Superintendent, Geological Survey of India.</td><td>Calcareous shales with the following compositions:—
<table>
<tr><th></th><th>A.</th><th>B.</th><th>C.</th></tr>
<tr><td>Insoluble in Hce.</td><td>51·01</td><td>19·21</td><td>12·51</td></tr>
<tr><td>Fe_2 O_3 and Al_2 O_3.</td><td>7·11</td><td>2·71</td><td>2·21</td></tr>
<tr><td>$Ca\ CC_3$.</td><td>36·27</td><td>76·09</td><td>84·13</td></tr>
<tr><td>$Mg\ CO_3$ (by difference).</td><td>5·61</td><td>1·99</td><td>1·15</td></tr>
<tr><td></td><td>100·00</td><td>100·00</td><td>100·00</td></tr>
</table>
</td></tr>
</table>

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Specimen found in Central India.	The Reporter on Economic Products to the Government of India.	Asbestos.
Mineral occurring in the mica-bearing pegmatites, at Tallapad, Nellore district (No. $\frac{13}{539}$).	Dr. T. L. Walker, Assistant Superintendent, Geological Survey of India.	Automolite (zinc-alumina spinel); specific gravity, 4·586.
Specimen from the Kohat district.	R. N. Hodges, Esq., Kohat, Bannu Railway Survey.	Gypsum.
Mineral from the Mica-bearing pegmatites, Chaganam, Nellore district (No. $\frac{13}{539}$).	Dr. T.L. Walker, Geological Survey of India.	Columbite; specific gravity, 5·748.
Four specimens from the Henzada district.	Deputy Commissioner, Henzada, through the Director, Land Records, Burma, and Reporter on Economic Products.	1. *From Shandaung S. W. of Lemyethna.* Ordinary laterite. 2. *Three miles N. of Pethalet.* Impure steatite. 3. *Found lying above No. 2.* Nodule of impure serpentine. 4. *Eight miles W. of Kyauktaung.* Decomposed iron-pyrites.
Specimen from Upper Burma.	Reporter on Economic Products.	Graphite schist.
Specimen from the Gaya district.	Chevalier O. Ghilardi, Vice-Consul for Italy, Calcutta.	Triplite.
Two specimens examined for gold.	G. Barton-Groves, Esq., Deputy Postmaster-General, Rajputana.	1. Quartz with specular iron. 2. Quartz with copper pyrites. Both specimens contain traces of gold.
Specimens of yellow clay from Katni, Jabalpur district.	The Under Secretary to the Chief Commissioner, Central Provinces.	Fuller's Earth.
Specimen for determination.	R. H. Morton, sq., Mal P.O., Jalpaiguri.	Rock crystal.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Two specimens for determination.	Reporter on Economic Products.	Iron-pyrites. Quartz in clay slate.
Specimen from Bankipur	Do. do.	Talcose schist.
Specimen from Bannu, Punjab.	Do. do.	Coal with small quantities of pyrite.
Three specimens from the Duars.	Do. do.	1. Dolomitic limestone. 2. Calcareous tufa. 3. Air-slaked lime.
Four specimens for determination.	F.B. Manson, Esq., Officiating Conservator of Forests, Tenasserim Circle.	1. Quartz with pyrite in veins. 2. Quartz with vesicular pyrite and ferrous sulphate traces 3. Iron pyrites. 4. Sand containing iron-pyrites, quartz, galena and schist fragments. The first two were found on assay to contain no gold.
Specimen said to be from Sikkim.	W. P. Masson, Esq., Darjeeling.	Coal, crushed and showing the usual characters of the Darjeeling Gondwana coal.
Two specimens from the Maw State of the Myelat in the southern Shan States, for gold.	M. Hunter, Esq., M.A., F.C.S., Chemical Examiner, Burma, Rangoon.	B. *Quartz.* Contains visible gold. C. *Quartz. Quantity received 1 lb. 6 oz.* Yielded on assay no gold.
Specimen of quartz with pyrites, for gold.	B. Houghton, Esq., C.S., Deputy Commissioner, Katha, Upper Burma.	*Quantity received 12½ oz.* Yielded on assay no gold.
Specimens found in the hills adjacent to Simla.	Sergeant W. Wren, His Excellency the Viceroy's Band, Simla.	Crystals of kyanite in sericite and chloritic schist.
Specimens of "calcareous cement" from Tavoy, Burma.	Geo. Watt, Esq., C.I.E., Reporter on Economic Products to the Government of India.	Cement found to contain much carbonate of lime and of very poor quality—structurally weak through, probably, use of imperfectly burnt lime.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Specimen from Hills near Nemakallu, Bellary.	Dr. Edgar Thurston, Superintendent, Government Museum, Madras.	Quartzite with fuchsite.
Specimen found on the banks of the Oubuikwin stream near Oubuikwin village, close to the Henzi basin.	F. B. Manson, Esq., Officiating Conservator of Forests, Tenasserim Circle, Rangoon.	Pyritous sand with pebbles of tinstone (cassiterite).
Specimen picked out of the hill side at Simla.	A. Richards, Esq., Alliance Bank of Simla, Ld., Simla.	Pyrite.
Specimen from Burma.	Dr. Geo. Watt, Reporter on Economic Products to the Government of India.	Arsenolite (As_2O_3) with small quantities of Realgar ($As\ S$) and Orpiment ($As_2\ S_3$). Sp. Gr. 3·69.
Seven Micro-sections of rocks collected during the season 1898-99 in Raipur, Kanker and Bustar.	P. N. Bose, Esq., B.Sc., F.G.S., Geological Survey of India.	Three slides of altered diabase, composed of augite partially changed to hornblende, and secondary minerals including quartz, lencoxene and epidote. One rock from Lakhimpuri, Kanker State, contained micro-pegmatite. Four slides of granitite-gneiss composed of quartz, orthoclase (microcline and micro-perthite), oligoclase, biotite, epidote, sphene, and zircon.
Specimen found in Kharagoda.	H. G. Bulkley, Esq., Assistant Collector of Salt Revenue, Kharagoda, Kathiawar.	Selenite.
Specimens from near Kangyam, Coimbatore district.	Capt. H. Monty Campbell, R.A.	1. Twinned crystals of muscovite, blue apatite, albite and microcline. 2 and 3. Corundum in felspar rock. 4. Garnets from old beryl mine. 5. Muscovite showing lines parallel to the pressure figure.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of Examination.
		6. Graphic granite. 7. Microcline. 8. Corundum. 9. Felspar with chrysoberyl and corundum.
Specimen from Ootacamund.	Capt. H. Monty Campbell, R.A.	Allophane.
A specimen of the dust which fell during a shower of rain at Simla on the 14th July 1899.	The Meteorological Reporter to the Government of India, Simla.	Contains, besides ordinary ferruginous clay, distinct traces of carbonate and phosphate of lime in a very finely divided state and agreeing chemically with dust from the Punjab plains.
Specimens found near Pendi, Hazaribagh district.	A. Mervyn-Smith, Esq.	Garnets, fresh and decomposed. Iron ore. Schorl. Apatite with quartz and felspar.
Specimens found in the Mawlu Township of the Katha district.	The Revenue Secretary to the Government of Burma, Rangoon.	Four packets mainly garnet. One packet contained, besides garnet, one small fragment of schorl, fragments of quartz, sapphire and 4 pieces of colourless topaz.
Specimen found in the southern Shan States.	Ditto ditto	Antimonial tetrahedrite, composed of sulphide of antimony and copper with smaller quantities of arsenic, iron, zinc, lead and silver, also weathered products, carbonates of copper, oxides of antimony and ferruginous clay.
Six specimens from Kila Drosh, Chitral country.	Lieutenant-Colonel R. W. MacLeod, Commanding 29th Punjab Infantry, Kila Drosh, Chitral.	Nos. 1, 2, 3, and 5, serpentines with varying quantities of rhombohedral carbonates. No. 4 volcanic ash, decomposed. No. 6 vein quartz with copper ore (sulphide and carbonates).

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of Examination
Specimens from the Maurbhanja State, Balasore.	Babu Tinkari Chowdhry, Maurbhanja, Balasore.	Limonite and hematite pseudomorphous after pyrite.
Two specimens for determination.	W. Pendlebury, Esq., Agent and Manager, H. H. the Nizam's Guaranteed State Railways Co., Limited, Secunderabad, Deccan.	1. Granite with pyrite filling cracks. Tested for gold without positive result. 2. Biotite-hornblende rock from segregation patch in the granite.
Specimen obtained from a bank recently raised above sea-level about 2 miles from Tagacherry off the coast at Quilon.	Dr. Edgar Thurston, Superintendent, Government Museum, Madras.	Foraminiferal and shell sand agglutinated into worm tubes.
Specimens from the Bendi area, Hazaribagh district.	A. Mervyn-Smith, Esq.	1. Melted lumps of metallic tin. 2. Scoriaceous "bloom" of tin and iron. 3. Hornblendic gneiss. 4. Pegmatite with purple garnet, etc. 5. Tourmaline with core of quartz.
Specimen said to have been procured from the Chota Nagpur Division.	Reporter on Economic Products to the Government of India.	Hematite sand with small quantities of magnetite.
Eight specimens from Chitral.	Lieutenant-Colonel R. W. MacLeod, Commanding 20th Punjab Infantry, Kila Drosh.	1 Buff-coloured marl. 2. Quartz impregnated with carbonates of copper, lime and magnesia. 3. Dolomitic veins in marl. 4. Mica-hornblende-pyroxene-peridotite approaching scyelite. 5. Silky schist with pyrite cubes. 6. Altered porphyrite. 7. Impure serpentine 8. Alteration product of schist.

List of Assays and Examinations made in the Laboratory during the past year—contd.

Substance and locality.	Sender.	Results of examination.
Specimen found in the Chanda district, Central Provinces.	A. E. Lowrie, Esq., Deputy Conservator of Forests, Chanda, Central Provinces.	Calcite crystals.
Specimen found in the Maurbhanja State, Balasore.	Tinkari Chowdhry, Maurbhanja, Balasore.	Slag.
One specimen for determination.	The Reporter on Economic Products to the Government of India, Calcutta.	Granular epidote.
Three specimens from Nagpur.	Ditto	Fuller's-earth, 3 varieties.
Specimens from Mobyniu, Katha district, Upper Burma.	C. M. P. Wright, Esq., Choukpazat Gold Mining Co., Limited, Upper Burma.	Rolled pebbles of black rutile.
Specimen quarried near Gwalior for ornamental purposes, and four specimens from Malwa.	Colonel D. G. Pitcher, I. S. C., Department of Land Records, Gwalior State, Morar.	Block of sandstone, and 1. Basalt. 2. Quartzose fault-rock with limonite. 3. Garnetiferous mica-schist. 4. Sericite schist.
Two packets of gems from a tributary of the Ledawchaung, Katha district, Upper Burma.	The Deputy Commissioner of Katha, through the Secretary to the Financial Commissioner of Burma, Rangoon.	*1st Packet contained*— Rubies, sapphires, green tourmaline, zircon, topaz, garnet, spinel and quartz crystals. *2nd Packet*— Sapphires, green and black tourmaline, topaz, quartz, felspar, garnet, spinel and ruby.

List of Assays and Examinations made in the Laboratory during the past year—concld.

Substance and locality.	Sender.	Results of Examination.
Stones found in a well of the Byturni Bridge, Cuttack district.	E. Beckett, Esq., District Engineer, Bengal-Nagpur Railway, Jenapur, Cuttack.	Six pieces of glass and two of quartz.
Specimens from the Chandon Estate, 8 miles north of Baidyanath Junction, East Indian Railway.	Henry Bateson, Esq., Gillanders, Arbuthnot & Co., Calcutta.	1. Muscovite weathered and broken in books of 2" to 3". 2. Cerussite and minium. 3. and 4. Quartz crystals. 5. Small piece of pegmatite. 6. Tourmaline (schorl). 7. Garnets. 8. Coal.
Rock from the village of Hatipota, 4 miles east of Bilasipara, Goalpara district.	Engineer-in-Chief, Eastern Bengal State Railway, Calcutta.	Granitoid gneiss (binary granite) suitable for ordinary structural purposes.
Specimen from Koraput, Vizagapatam district.	Dr. T. L. Walker, M.A., Geological Survey of India.	Limonite.
Specimens from the Chandon Estate, 8 miles north of Baidyanath Junction, East Indian Railway.	Henry Bateson, Esq., Gillanders, Arbuthnot & Co., Calcutta.	1. Black tourmaline (schorl). 2. Coal (not obtained *in situ*). 3. Ilmenite. 4. Oxide and carbonate of lead. 5. Garnets.
Specimen from the Darjeeling district.	Pell & Co., Calcutta.	Yellow ochre.

MR. F. R. MALLET.
Langbeinite.

Mr. F. R. Mallet has continued to show his interest in the work of the department by the publication, since his retirement from the service, of researches bearing on the mineralogy of India. His latest work consists of an investigation of the mineral langbeinite, a double sulphate of potash and magnesia, which occurs as a constituent of the deposit of potash salts discovered by Dr. H. Warth in the Mayo Salt Mines in 1873. The existence of the compound $K_2\,SO_4, 2\,Mg\,SO_4$ as a definite mineral constituent of this deposit has now been established by Mr. Mallet, who has also prepared the mineral artificially by fusing together the two sulphates in proper proportions (*Min. Mag.*, Vol. XII, 1899, p. 159), and has extended his researches by artificially preparing a number of allied double sulphates cf the general form $2\,M''\,SO_4, R'_2\,SO_4$ (*Trans. Chem. Soc.*, Vol. 77, 1900, p. 216).

2.—PALÆONTOLOGICAL WORK.

Collections.

A record of good work and actual progress has been established during the past year in this most important branch of the Survey, both in India and through our scientific helpers in Europe.

a. IN INDIA :—

DR. NOETLING *on Miocene fossils of Burma.*

The Palæontologist of the Department, Dr. Fritz Noetling, continued the description of the large collections from the miocene beds of Burma. This work has been already mentioned in the General Reports of 1898 and 1899; it is now finished and will be published in THE PALÆONTOLOGIA INDICA.

Dr Noetling has taken much trouble in dealing with this subject which, owing to the almost total absence of any literature of reference, was particularly intricate, and in order to arrive at a correct idea as to the true relationship of this fauna, he was obliged to compare the fossil specimens with their living relatives inhabiting the Indian Ocean. This necessitated of course a good deal of extra work, not generally connected with the study of fossils, but the results are very satisfactory, and Dr. Noetling's memoir will remain a standard work for the study of the tertiary fauna of India, particularly as he has indicated a new direction which researches of this kind should take in future. The main results are the following:

The living fauna of the Indian Ocean has partly descended from the fauna of the miocene period inasmuch as 30 per cent. of that fauna still exist in a living state. On the other hand, it seems certain that the fauna of the Indian Ocean contains a foreign element, the ancestors of which have not yet been found in a fossil state in India.

Dr. Noetling has carefully studied the relationship of the remaining 70 per cent. of the miocene fauna, which represents the "extinct" element of the fauna of the Indian Ocean.

He was able to distinguish four classes, *viz.*:—

(1) Species of which no relative, either living or fossil, could be traced.

(2) Species which show the closest relationship to species occurring in the eocene of France.

(3) Species which show the closest relationship to species living at present in the western province of the Pacific Ocean, but which do not occur in the Indian Ocean.

(4) Species which show a close relationship to species living at present in the Mediterranean.

Dr. Noetling thinks that the first group represents the "indigenous" element, that is to say, species which are closely related to such which occur in the older tertiaries. He states that this view has been fully confirmed by the study of the fossils collected by him in the eocene of Sind where he discovered numerous species identical with such included in the above group.

The second group which he calls "Gallic types" proves that an intimate connection must have existed between the eocene fauna of Europe and the miocene fauna of Burma. This connection can only be explained by the theory of a migration of species from west towards east which commenced with the eocene period, and lasted probably up to quite recent times. This theory is greatly supported by the occurrence of the third group, which he calls "Pacific types," the existence of which can only be explained under the supposition that towards the end of the miocene period the representatives of this group migrated further eastwards, while they died out in the region of the Indian Ocean. The above four groups are called "palæogene species" in opposition to the "neogene" species which are again subdivided into three groups. According to Dr. Noetling the fauna of the miocene of Burma would therefore be composed as follows:—

Palæogene species.	Indigenous types	36·2 %
	Gallic types	13·8 %
	Pacific types	18·6 %
	Mediterranean types	1·2 %
	Species not classified	0·6 %

Neogene species.	Identical species	11·4 %
	Sub-identical species	11·4 %
	Evolutionary species	4·8 %
	Species not classified	2·4 %

This fauna lived in a very shallow sea not exceeding 25 metre in depth, and as there are several fossiliferous horizons succeeding each other in vertical direction in a series measuring not less than 2,450 feet in thickness, the deposit of the miocene beds must have accumulated during a time of rapid subsidence.

A further and most interesting fact is the proof that the miocene of Burma does not share a single species in common with the miocene fauna of Europe, but exhibits a great similarity with the miocene of Java and Sumatra on one side and the fauna of the Gaj beds of western India on the other side.

The stratigraphical part of the memoir deals with the subdivision of the tertiaries in Burma in general, and the miocene of Burma in special, which is illustrated by a number of characteristic sections.

Dr. Noetling's memoir is not only very important from a purely scientific point of view, but it permits definite conclusions to be drawn with regard to the occurrence of petroleum and coal in Burma, which we now know to occur in the lower miocene only.

DR. F. NOETLING.
Permian and triassic fossils of the Salt Range.
Tertiary fauna of Sind.

During the last field season Dr. Noetling was on tour in the Salt Range and later in Sind, from which localities he has brought away a magnificent collection of fossils which will require much time to determine and describe. New light has been shed through these fossils on the relations of the permo-trias sections of the Salt Range, whilst the lower tertiary fossils of Sind will form one of the most important additions to our collections. This work, which was done during the last month or two with Mr. Vredenburg as assistant, is noticed in Part II of this Report.

DR. A. VON KRAFFT.
Triassic Fossils of the Himalayas.

The palæontological work accomplished by Dr. von Krafft during the cold season of 1899-1900, was of a two-fold nature. It consisted, first, of an examination of the very large collections obtained in Spiti by Mr. Hayden and himself during the summer of 1899, the results of which are embodied in Part III of this Report.

Secondly, a beginning was made with a systematic description of the recently made collections from the trias of the Himalayas.

These fossils were brought together in 1898 and 1899 by Messrs. Hayden and Dr. von Krafft from Spiti, and by Messrs. LaTouche, Smith and Walker from the Central Himalayas. They consist for the greater part of Cephalopoda and include representatives of the whole series of trias beds.

Of these collections the lower triassic ammonites have been almost completely determined. The following ammonites have been described :—

(1) Twenty-two new species, belonging to the genera *Meekoceras* (12 sp.), *Hedenstrœmia* (4 sp.), *Flemingites* (1 sp.), *Clypites* (1 sp.), *Pseudosageceras* (1 sp.), *Danubites* (1 sp.), *Ceratites* (1 sp.), *Lecanites* (1 sp.).

(2) Five previously described, but of which a revised description seemed desirable, *viz.* :—

Meekoceras hodgsoni, Dien.
" *varaha*, Dien.
Hedenstrœmia mojsissovicsi, Dien.
Danubites kapila, Dien.
" *nivalis*, Dien.

(3) Seven species, which previously had not been known to occur in the Himalayas, and had so far only been known either from the Salt Range or the lower triassic deposits of northern Siberia (mouth of the Olenek River), namely :—

Meekoceras cf. pulchrum, Waag. (Salt Range).
" *aff radiosum*, Waag. (" ").
Danubites radians, Waag. (Salt Range).
" *rotula*, Waag. (" ").
Proptychites ammonoides, Waag.
" sp. aff. *latifimbriato*, Waag.

The chief stratigraphical result to which these palæontological researches have led, is, that the Otoceras beds of the Himalayas do not, as was hitherto believed, correspond to the beds at the base of the lower ceratite limestone of the Salt Range, but are equivalent to the ceratite marls and the lower ceratite sandstones, and very probably include also the lower ceratite limestone, while, on the other hand the upper division of the lower trias of the Himalayas ("Subrobustus beds," Diener) does not correspond to the whole of the ceratite sandstones, but merely to the two upper divisions of the same, *viz.*, the Stachella beds and the Flemingites flemingiarus beds.

MR. T. D. LATOUCHE. MR. F. H. SMITH. DR. T. L. WALKER.

During the rains of 1899 it was possible to depute three officers to the higher ranges of the Kumaon Himalayas to revise certain sections surveyed by me in former years, and also to collect more fossils in certain localities. A very large collection of fossils was made during these tours and is now awaiting description. The triassic collection made by Mr. Smith is particularly interesting and has been partly worked out by Dr. von Krafft; the older palæozoic fossils, chiefly found by Mr. LaTouche, will be sent to the British Museum, where older collections belonging to the Department are already awaiting description. Dr. Walker fell ill during his deputation, but not before a small, but interesting suite of fossils was obtained from the classic locality of Chitichun, north-east of the Milam passes.

MESSRS. LATOUCHE, MIDDLEMISS AND DUTTA. *Palæozoic fossils of Burma.*

During the progress of surveys carried on in the Shan hills during the last field season, Messrs. LaTouche, Middlemiss and Dutta acquired a most interesting series of palæozoic fossils. Most of them are either of silurian or devonian age. Mr. Middlemiss discovered permian fossils in the southern Shan States, but his efforts to trace the locality into the Karenni country, where triassic fossils were supposed to have been found, failed entirely.

a. IN EUROPE :—

The description of our fossil collections which have been entrusted to scientists in Europe, is progressing apace. The following gentlemen are at present at work on them :—

In England.

Dr. F. L. KITCHIN, Geological Survey of England and Wales.	Jurassic *lamallibranchiata* of Cutch.

Dr. Kitchin will probably also undertake to describe the silurian fossils of the Himalayas.

In Austria.

PROF. DR. W. WAAGEN, University of Vienna.	Triassic fossils of the Salt Range.
PROF. DR. UHLIG, University of Prague.	Jurassic fossils of Himalayas.
DR. F. KOSSMAT, K. K. Geologische Reichsanstalt.	Cretaceous fossils of Assam.

In France.

PROF. R. ZEILLER, Ecole Nationale Supérieure des Mines, Paris.	Gondwana fossils.

DR. WAAGEN.

It is with the utmost regret that I have to record the death on the 24th March last in the 59th year of his age of Dr. Wilhelm Waagen, Professor of Palæontology at the University of Vienna, which took place after a lingering illness of several years' duration. Dr. Waagen was appointed to the Department in December 1870 and he had to retire on the 25th August 1875 in consequence of illness contracted during the progress of his researches in India. He was one of our oldest friends and fellow-workers and was almost up to the very last employed in describing the fossils of the Salt Range, which work has been left unfinished. Although later research has added much to our knowledge of the distribution and character of the permian and triassic faunæ of India and has in a measure contradicted some of the results arrived at by Dr. Waagen, it may still be said that this great palæontologist's work has laid the foundation to our more advanced knowledge, and that the enthusiasm and industry which Waagen brought to bear upon Indian palæontology will be greatly missed by us all.

PROFESSOR E. SUESS.

The most responsible duties in connection with the direction of the palæontological work carried on in Austria for the Department, and the auditing of the disbursements on behalf of the same, has been ably and generously conducted by Professor E. Suess during the year under report, as it has been done by him for many years past.

3.—PUBLICATIONS.

The following publications were issued during the past twelve months:—

General Report.

General Report on the work carried on by the Geological Survey of India from the 1st April 1898 to the 31st March 1899.

Memoirs.

Memoirs, Volume XXIX, Report on the great Earthquake of the 12th June 1897 by R. D. Oldham.

Palæontologia Indica.—

Palæontologia Indica.

Series XV, Himalayan fossils. Vol. I, Part 2.—Anthracolithic fossils of Kashmir and Spiti by Dr. Carl Diener.

Series XV, Himalayan fossils. Vol. III, Part 1.—Upper Triassic Cephalopoda Faunæ of the Himalayas by Dr. Edmund Mojissovics.

New Series, Vol. I. No. 1.—The Cambrian fauna of the Eastern Salt Range by Dr. K. Redlich.

New Series, Vol. I. No. 2.—Notes on the Morphology of the Pelecypoda by Dr. F. Noetling.

Reports of the Inspector of Mines.

Mr. Grundy, the Inspector of Mines in India, sent in the following reports which were published during 1899-1900:—

1. Report on the Inspection of Mines in India, for the year ending 31st December 1898.
2. Report on the Inspection of the Coal-mines belonging to the Assam Railways and Trading Company, Limited.
3. Report on the Inspection of the Coal-mines in the Sor range of Hills near Quetta and at Mach.

Library.—The additions to the library during the year 1899-1900 amount to 1,890 Volumes, of which 1,185 were acquired by presentation and 705 by purchase. A detailed list of acquisitions is given in Appendix I.

Personnel.

Notification by the Government of India published in the "Gazette of India," dated 6th May 1899, Part I.—Leave.

Department.	Number of order and date.	Name of Officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Revenue and Agricultural Department.	Notification No. 1404-50-2, dated 5th May 1899.	R. D Oldham, Superintendent, Geological Survey.	Furlough for one year and 6 months.	11th July 1899	...	Availed of subsidiary leave from 6th to 10th July 1899.

Notifications by the Geological Survey of India published in the "Gazette of India," Part II.—Leave.

Department.	Number of order and date.	Name of Officer.	Nature of leave.	With effect from	Date of return.	REMARKS.
Geological Survey of India.	Notification No. 414, dated 28th April 1899.	P. N. Bose, Deputy Superintendent, Geological Survey.	Privilege leave for 1 month and 15 days.	15th May 1899.	30th June 1899.	*Gazette of India* dated 6th May 1899.
Ditto .	Notification No. 249, dated 13th March 1900.	T. L. Walker, Assistant Superintendent, Geological Survey.	Privilege leave for 28 days.	17th April 1900 or subsequent date.	...	Availed on 19th April 1900. *Gazette of India*, dated 24th March 1900.
Ditto .	Notification No. 252, dated 13th March 1900.	D. La Touche, Superintendent, Geological Survey.	Privilege leave for 3 months.	15th April 1900 or subsequent date.	...	

Notifications by the Government of India published in the "Gazette of India," Part I.—Appointments, Confirmation, Promotion, Reversion and Retirement.

Department.	No. of order and date.	Name of Officer.	From	To	Nature of appointment, etc.	With effect from	REMARKS.
Revenue and Agricultural Department.	Notification No. 1533-56-2, dated 12th May 1899.	T. H. Holland	Deputy Superintendent, Geological Survey.	Curator, Geological Museum and Laboratory.	Substantive, permanent.	1st May 1899.	*Gazette of India*, dated 13th May 1899.
Ditto .	Notification No. 2681-50-8, dated 12th August 1899.	Ditto .	Ditto .	Superintendent, Geological Survey.	Substantive, temporary.	6th July 1899.	*Gazette of India*, 12th Aug. 1899.
Ditto .	Ditto .	H. H. Hayden	Assistant Superintendent, Geological Survey.	Deputy Superintendent, Geological Survey.	Ditto .	Ditto .	
Ditto .	Letter No. 1675-61-2, dated 22nd May 1899.	T. L. Walker .	Ditto .	......	Substantive, permanent.	8th May 1899.	Confirmed.
Ditto .	Notification No. 3640-81-4, dated 13th Oct. 1899.	G. A. Stonier .	Mining Specialist, Geological Survey.	......	Substantive, temporary for 5 years.	4th October 1899.	*Gazette of India*, dated 4th Oct. 1899.
Ditto .	Notification No. 3873-81-10, dated 10th Nov. 1899.	G. F. Reader .	Coal Specialist, Geological Survey.	......	Ditto .	1st November 1899.	*Gazette of India*, dated 11th Nov. 1899.
Ditto .	Notification No. 1300, dated 11th April 1900.	F. H. Hatch .	Gold Mining Expert, Geological Survey.	......	Substantive, temporary for one year.	31st March 1900.	*Gazette of India*, dated 14th Apl. 1900.

Part II.—Field Parties.

Distribution of Officers.

During the year ending 31st March 1900 the officers of the Department were distributed as follows :—

Mr. R. D. Oldham .	. Head-quarters till 5th July 1899; then furlough for 18 months.
SUPERINTENDENTS.	
Mr. T. H. D. LaTouche	. Head-quarters till 29th June 1899; Kumaon Himalayas till 1st October; at Delhi with Austrian Leonid Expedition during October; left head-quarters on the 26th November 1899 for the northern Shan States, Burma.
„ C. S. Middlemiss	. Head-quarters till 26th November 1899; then southern Shan States and Karenni country, Burma.
DEPUTY SUPERINTENDENTS.	
Mr. P. N. Bose .	. Head-quarters till 14th October 1899; then Central Provinces.
„ T. H. Holland .	. Head-quarters; in charge of Museum and Laboratory.
„ P. N. Dutta .	. Head-quarters till 3rd November 1899; then northern Shan States, Burma.
„ F. H. Smith .	. Head-quarters till 24th June 1899; Kumaon Himalayas till 14th October; then Ganjam, Madras Presidency.
ASSISTANT SUPERINTENDENTS.	
Mr. H. H. Hayden .	. Spiti Himalayas till 4th November 1899; then Wynaad, Madras Presidency.
„ E. Vredenburg .	. Baluchistan till 7th July 1899; head-quarters till January 1900, and then Punjab and Sind.
„ Th. L. Walker .	. Head-quarters till 24th June 1899; Kumaon Himalayas till 24th September, and then Vizagapatam, Madras Presidency.
Dr. A. v. Krafft .	. Spiti Himalayas till 4th November 1899; then head-quarters.

PALÆONTOLOGIST.	
Dr. F. Noetling	Head-quarters till 11th September 1899; then Punjab and Sind.
MINING SPECIALISTS.	
Mr. G. A. Stonier	Left head-quarters 17th November 1899 for the Wuntho district, Burma.
" G. F. Reader	Left head-quarters on the 10th November 1899 for the coal-fields of Rampur and Baghelkand.
SUB-ASSISTANTS.	
Lala Hira Lal	Head-quarters till 10th November 1899; with Mr. Reader in Baghelkand.
" Kishen Singh	Head-quarters till 17th November 1899; then with Mr. Stonier in Burma.
MUSEUM ASSISTANT.	
Mr. T. R. Blyth	At head-quarters till 29th January 1900; then proceeded on deputation to Paris in charge of exhibits.

Division of work.—The surveys were again divided as far as practicable into purely economic and scientific inquiries.

A.—Economic Inquiries.

1. GOLD.

Since the publication of Vol. III of the Manual of the Geology of India in 1881, gold mining in India has become an important industry, and the most sceptic persons must have become convinced that with proper management and economy many of our gold ores might be exploited to great advantage. At the present time, when owing to the introduction of metallurgical processes, quite unknown not long ago, it has become possible to work exceedingly low grade ores profitably, it is of great importance to study the question in all its bearings, and it has therefore been decided that full reports be drawn up on the mode of occurrence and nature of the auriferous rocks of the most important localities in India.

The most important areas in this respect are Burma and southern India; the work in Burma has been put in charge of Mr. G. A. Stonier, whilst Mr. H. H. Hayden has begun the inquiry in the Wynaad. Both have given (see Part III) preliminary accounts of their surveys, which will be continued duing the greater part of next year (1900-1901). The well-known expert in gold mining, Dr. F. H. Hatch, joined the staff of the Department on the 31st March of this year and will conjointly with the officers named above, continue the study of gold in India, and the result of this joint inquiry will then be published as part 3 of the Manual of the Geology of India.

Burma.

MR. G. A. STONIER.
LALA KISHEN SINGH.

Investigations were practically confined to the Wuntho district only, and a preliminary report on the results of this season's work is given in Part III. The district is evidently fairly well provided with auriferous reefs, though up to date all the leaders and reefs which have been examined were very limited in dimensions. There is no doubt of the presence of gold in paying quantities, whilst in some cases the reefs may even be called rich, but there remains doubt whether there is sufficient ore to repay working it on a large scale, which alone would ensure commercial success. Towards the end of March Mr. Stonier came across what appears to be a promising quartz-reef near Baumark, which runs to 9 dwts. over a width of 9 inches. He is now engaged in testing the extent of the reef.

Wynaad.

MR. H. H. HAYDEN.

A preliminary examination of the more important reefs of South and South-East Wynaad was carried out during the months of November to March of last year, a short report on which will be found in Part III. This survey will be continued on a larger scale during the next year by Mr. Hayden and Dr. F. H. Hatch. The results obtained by Mr. Hayden during his preliminary inquiry "tend to show that the majority of the reefs are probably too poor in gold to offer any prospects of remunerative working, yet it is possible that one or two may prove sufficiently rich to justify mining operations, provided they are carried on judiciously and under strictly expert supervision."

2. COAL.

Coal in Bikanir.

I have had occasion to re-visit Bikanir on my late tour in Rajputana and have ascertained that the question of the coal-field of Palana, referred to in my General Report of last year (p. 33), stands now practically as it did then. A good deal further development of the known seam has taken place at the same locality, but no borings have been conducted and it is unknown whether there are other seams below the one worked, and in what direction and to what distances the field extends. The Durbar had been advised by the State Engineer that the actual "proving" of the field is unnecessary, as, so I am told, sufficient coal is actually in sight for probable requirements on the Jodhpur-Bikanir Railway for a space of 15 years.

I still am of opinion that the field should be proved both vertically and horizontally; the position of it, midway as it will be between the North-Western, East Indian and Bombay Railway systems, marks it as one of the most important coal localities of India.

Rampur and Sohagpur coal-fields.

Mr. G. F. Reader, the coal-specialist of the department, examined at some length the coal-fields of Rampur (Eeb-river) and of Sohagpur, somewhat detailed reports on which are published in Part III of this Report.

Mr. Reader comes to the conclusion that as regards the Rampur field, further action should be directed towards the immediate exploitation of the "*Eeb coal seam*" and the completion of bore-hole No. 4 (K^4 of map) down to the Talchirs.

In the Sohagpur coal-field Mr. Reader finds that out of seven seams two (the Sabo and Amlei-Bokahi), are of workable thickness and very fair quality.

3. LANDSLIP AT DARJEELING.

MR. HOLLAND.

For three weeks during last October Mr. T. H. Holland's services were placed at the disposal of the Bengal Government to advise the Committee "appointed to inspect the buildings, roads and drains in and round the town of Darjeeling after the disaster of the 24th September 1899, ... and to suggest measures ...... to prevent the occurrence of landslips in Darjeeling in the future......" The general conclusions of the Committee and reports of the Sub-Committees were published together with the thanks of the Local Government, in the *Calcutta Gazette* of the 7th December last. The numerous and destructive landslips were, it appears, confined to the soil-cap covering the gneissose formation which forms the Darjeeling ridge, and their immediate cause was satisfactorily traced to the excessive rainfall which, following an unusually heavy monsoon, deluged Darjeeling on the two days preceding the disaster.

The details of the Committee's lengthy report are purely of local interest but their conclusions as to the conditions for the development of soil-cap slips being in general agreement with the principles outlined in Mr. Holland's report on Naini Tal. I should like to endorse the following remarks for the beneficial warning of authorities in other hill stations which have hitherto escaped the punishments which have been meted out to Naini Tal and Darjeeling:—" Although it is true that the cause of slips recently examined (in Darjeeling) can be immediately traced to the heavy rain of September 24th—25th, it must not be forgotten—and this is a lesson of permanent value to all hill stations—that the necessary facilities have been in the course of gradual development for many years. The soil-cap is the direct product of the atmospheric decomposition of the rocks, and through the action of percolating meteoric waters is in process of continual growth at the superficial expense of the latter. The removal of soil from the surface by the mechanical action of running water, and the simultaneous addition of decomposition products below the sub-soil by the chemical activity of percolating water are not concurrently compensatory in slopes covered with vegetation: there is a balance in favour of the latter process which is periodically restored by slips from the surface. The formation of a soil-cap does not in itself contribute to an increase in the surface slope, but its removal from the foot of a slope by streams, which there acquire a greater erosive activity through increased velocity and volume, increases the average slope of the hillside....... The increase in the angle of a slope by the undermining action of a river is supplemented by the slow process of creep which proceeds step-fashion in every inclined soil-cap with the regular succession of wet and dry seasons. The expansion which follows the saturation of a soil-cap during each monsoon naturally takes place in the direction of least resistance, which is down the hillside. The desiccation which follows in the succeeding dry season merely makes a pause in this movement—not a return to original conditions. Such a ratchet-and-paul kind of creep downwards and outwards proceeds until the conditions of stability are exceeded, and a landslip occurs to restore equilibrium. It is delusive, therefore, to suppose that, because a slope has apparently withstood the action of twenty monsoons, the absence of accident is an index to its stability and an insurance against danger in the twenty-first wet season. On the contrary, in a steep earth slope unprotected by artificial means, every monsoon brings it nearer to the inevitable landslip, and the more perfect appreciation of this fact by the authorities in our hill stations will help to guard against the constant, but fatal, tendency there always appears to be to repose confidence in a slope which has not by chance been the scene of an accident for a generation." Although this warning would not be applicable in the case of slopes on massive dolomite, as in parts of Mussoorie and Naini Tal, or on quartzite, as in parts of Simla, most of the Himalayan stations include slate and shale formations, or are covered with thick soil-caps which should never be allowed to exceed the angles of safety which have been determined for different degrees of saturation.

4. IRRIGATION.

Bhavani dam.

In Part III I give Mr. T. H. Holland's report on the site of the Bhavani dam. This note, referred to in my last Report, has since been published by the Madras Government, who have also recorded their thanks for Mr. Holland's services on the Committee appointed to investigate the Bhavani project.

Artesian water-supply.

During February and March I visited certain portions of the Central Provinces, Gujerat and Rajputana to ascertain, if possible, the chances of increasing the existing water-supply by means of artesian borings. Public attention had been directed to these means of alleviating the chances of famines in India, and in some measure it had been insinuated that Government neglected its duties by not resorting more frequently to artesian well-sinking in certain districts in India. That this is not so is shown by the immense mass of official papers on the subject, which I am directed to notice in a compilation on the subject about to be published. Actual attempts had been made to sink artesian wells in different parts of India, but it must be owned, with indifferent success in most cases. Practically the only instance in which a water-supply has been thus obtained within British India, is the one afforded by the wells in the Quetta District, which are a decided success. It must be borne in mind that for purposes of finding artesian water the Peninsula of India may be divided into three great areas: (1) The Indo-Gangetic plains, (2) The Peninsula proper lying south of the Ganges alluvium, and (3) portions of the tertiary plains of the Rajputana desert, Gujerat and Sind.

1. The Indo-Gangetic plains are mostly formed of immense thicknesses of alluvial deposits in which artesian conditions seem to be absent. The deposits are probably of such thickness that it would be hopeless to try and penetrate the same down to the water-level. Borings have been made down to 1,800 feet thickness without meeting with any other but soft sands and sandstones through which water passes without let or hindrance. From the character of the beds where seen near the margins of the basin, it seems that the same character of permeability attaches to the entire immense thickness of this alluvium, which may be upwards of 20,000 feet.

2. The peninsula proper south of this last area consists mostly of either igneous and schistose rocks overlaid by systems of old palæozoic formations and great sheets of basic eruptive rocks (Deccan trap). These rocks, although in some measure absorbent and water-retaining, offer such poor chances of finding artesian conditions, that it would in most cases be a waste of time and money to attempt boring for artesian water.

3. In Rajputana, Gujerat and Sind conditions are somewhat different. There we find tertiary (eocene and miocene) marine beds spread over a considerable area, lying within well-defined basins or forming wide-spread, gently sloping, almost undisturbed deposits. It is probable that in the greater portion of the Rajputana desert these deposits may be found below the recent accumulations of sands and alluvial formations. In that part of Gujerat forming the drainage basins of the Gulfs of Cutch and Cambay, and also in parts of Sind the conditions are similar, and as a matter of fact a good supply of water is met within moderate depths from the surface within the tertiary beds. As the latter, particularly the upper nummulitic limestones, contain strings and layers of salt, it follows that the water of that horizon is generally brackish.

At ordinary times this water, although to some degree always brackish, is used for domestic purposes and irrigation by the people of Rajputana and Gujerat, but during periods of drought the supply diminishes and then the water becomes almost brine and is useless alike for domestic and agricultural purposes. Attempts have been made at different times, as much as sixty and more years ago, to sink deep wells and artesian borings at several places in Gujerat, but the results were generally disappointing. The water obtained was found to be generally brackish; in one or two bore-holes it rose to within a few feet of the surface, but true artesian conditions have not been met with. It is true that none of these borings exceeded a few hundred feet, and it is difficult to form any workable deductions from the attempts.

When travelling in Gujerat and Kathiawar recently, I satisfied myself that there is no difficulty in obtaining plenty of water, even during the present season of drought, in places such as the vast plains of Gujerat, south and south-west of Ahmedabad. The natives have sunk a number of new wells at several places in that area and find water, only slightly brackish, within 40 to 50 feet from the surface. This water collects within the upper tertiary (miocene) beds, and it is probable that there are several well-defined horizons of such water. The tertiary deposits are underlaid in Gujerat by cretaceous rocks, which may be seen to outcrop along the borders of Kathiawar and Gujerat from under the traps which cover the greater part of the cretaceous beds. As far as these latter may be seen, they consist of dark-brown sandstones overlaid by light-coloured impure calcareous sandstones and marls. The latter act more or less as an impervious layer, whilst the porous brown sandstones beneath contain a good supply of water. It may be observed that wherever the upper marls have been removed by quarrying (near Wadwan for instance) the water contained in the sandstones below rises rapidly to the surface. Although slightly brackish, it is fit for domestic use.

It appears probable that these conditions will be found to prevail over a considerable part of Gujerat, and it may be, also in Rajputana, and I have therefore decided that it would be advisable to make a trial boring somewhere in the neighbourhood of Wadwan, this boring to be brought down to at least 1,000 feet or until the brown cretaceous sandstone is reached. There is some hope that the water reached in that horizon may then rise to the surface. Similar arguments may be urged in favour of certain localities in Rajputana, and I believe the Jodhpur Durbar has accepted my advice and will sink a deep boring between the Luni river and Balmer with the double purpose of finding an artesian supply of water and to ascertain also, whether the eocene coal seams of Bikanir are repeated within the tertiaries which most probably underlie the recent deposits near Balmir.

B.—Geological Surveys.

1. BURMA.

MR. T. H. D. LATOUCHE.
MR. C. S. MIDDLEMISS.
MR. P. N. DUTTA.

During the season 1890 to 1891, Dr. Noetling made a geological traverse through the northern Shan States; since then the topographical maps of the latter have been much improved upon and it was therefore decided to carry out a more systematic geological survey of the Shan States of Burma and a traverse of the adjoining Karenni country. Messrs. LaTouche and Dutta worked along the section between Mandalay and the Kunlon Ferry of the Salween, whilst Mr. Middlemiss conducted a rapid traverse through the southern Shan States and the Karenni hills. The results obtained are exceedingly interesting; in the northern Shan States some additions were made to the geological notes on the country given by Dr. F. Noetling[1] and some fossils were collected which await description.

The results are embodied in progress reports in Part III of this Report; Mr. LaTouche comes to the following conclusions :—

"The formations met with along the route traversed by me, that is, the railway line under construction between Mandalay and the Kunlon Ferry, are the following, in descending order :—

List of Formations.

No.	Period.	Description of beds.	Local Name.
11	Recent . .	Valley gravels and alluvial deposits with numerous land and fresh-water shells. Older gravels and boulder beds. Red and yellow clays, often of great thickness, and sometimes consolidated by the infiltration of carbonate of lime into a hard rock containing land and freshwater shells. Similar clays hardened by infiltration of iron oxide, laterite, occasionally sufficiently rich to be used as an ore of iron.	

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[1] Records, G. S. I., Vol. XXIII, p. 78, and XXIV, pp. 99, 119, 125.

List of Formations—(concluded).

No.	Period.	Description of beds.	Local Name.
10	Tertiary . .	White and yellowish sandstones with grey and brown clays and coal seams.	
9	Devonian ? .	Red and brown sandstones with numerous bands of red clay and shale. Few fossils.	Namyao beds.
8		Grey and olive shales with concretionary masses of dark blue limestone. Very fossiliferous.	Kyinsi beds.
7	Upper Silurian ? .	Thick beds of limestone generally siliceous, or calcareous sandstone, white or grey colours with subordinate bands of argillaceous shale or fuller's earth. The shales contain many fossils.	Maymyo limestone.
6	Upper Silurian .	Black calcareous shales with bands of hard black or dark grey limestone. *Graptolites*, etc.	Zebingyi beds.
5		Soft yellow sandy shales and sandstones with nodular beds of limestone. *Trilobites*, etc.	
4	Lower Silurian .	Grey and olive green shales and limestones weathering into soft sandy shales. Many fossils.	Naung Kungyi beds.
3		Flaggy limestones separated by bands of shale or clay, occasionally carbonaceous. *Orthoceras*, etc.	Myaungbaw beds.
2	Lower Silurian .	Dark red calcareous shales with *Echinosphærites Kingi* and fragments of crinoids.	Red crinoid beds (Pyinthu beds, Nœtling).
1		Massive and flaggy limestones traversed by numerous veins of calcite.	Sedaw limestone. (Mandalay limestone, Nœtling.)

These beds seem to form a conformable sequence, but as each sub-division from the red sandstones downwards, has been greatly crushed, folded, and faulted and the dips often vary considerably both in direction and amount within a space of a few yards, and, moreover, this line of contact between any two formations is generally concealed, it is impossible at present to say whether there is any unconformability or not. No mesozic formations were met with.

Generally speaking there is a distinct zonal arrangement of the different formations, the oldest occurring along the western edge of the hills ; while as we proceed eastwards newer formations are successively crossed. The general strike is between N.N.E. and E.N.E. but it varies greatly within short distances. This is also the general direction of the route taken, so that it often ran for several miles on one and the same formation.

The most interesting of the new formations discovered are the black graptolite shales with the underlying trilobite beds of the Zelingyi beds (Nos. 5 and 6). In the former *graptolites* are very numerous, often matted together on the surface of the layers. They appear to belong entirely to the monoprionidian order, no double forms being met with. They are associated with large numbers of another upper silurian fossil, closely resembling, if not identical with, *Tentaculites elegans* (Barr.) ; in fact the figures of this fossil in Barrande's Silurian system of Bohemia, Vol. III., pl. 14, might have been drawn from one of the Zelingyi shales. The *trilobites* are not so easily identified, being all fragmentary, but one or two specimens of heads are almost certainly those of *Eucrinurus punctatus*. *Fenestella retiformis* is also very common in these beds in one locality. The graptolite and trilobite beds are well seen in the railway cuttings on either side of Zebingyi Railway Station.

The shales and limestones of the Naungkangyi beds (No. 4) contain large numbers of casts of *Orthis* and *Strophomena*. Associated with these are numerous plates of a small cystirlean closely resembling *Mimocystitis Bohemicus* (Barr.) figured in Vol. VII, pl. 28, of Barrande's Silurian system of Bohemia. These belong to his stage D_2, corresponding to the Bala or Caradoc stages of Great Britain. These beds are well exposed in the Goktei gorge between the 84th and 86th miles on the cart-road. They also occur in the low hills about two miles north of Maymyo.

The white siliceous limestones (No. 7) are the most widespread formation found along the route. They extend from near Thondaung (Waboye) station about eight miles west of Maymyo, almost without a break to the Salween, a distance of nearly 200 miles. The only fossils they contain are the casts of small gastropods and a bivalve resembling *Pterinea*, but some shales found at Wetwun, twelve miles east of Maymyo, and again on the railway two miles north of Gokteik station, contain a fair number of fossils, which await identification, and are probably interstratified with these limestones. The latter form the precipitous cliffs on either side of the Gokteik gorge and about Lashio.

(No. 8.) A highly fossiliferous band of shales is found overlying the white limestone, but the fossils from it have not yet been specifically determined. They contain a small *Conocardium* and numerous specimens of *Pecten*, also a small gastropod, perhaps a *Murchisonia*. They may be of Devonian age. These were found in two localities: first near the village of Kyankyau, at the 73rd mile on the cart-road, and again near Kyinsi, from which village I have named the stage, at the 123rd mile. These beds occur at the base of a great thickness of red sandstones and shales (No. 9) which are especially well seen in the railway cuttings along the valley of the Mamyao or Lashio river. Here I found a few fossils in them, but all in a very fragmentary condition."

Southern Shan States and Karenni.

Mr. Middlemiss arrived at his working-ground in the southern Shan States on the 7th December, and he left it to return to head-quarters on the 4th April 1900.

Between those dates he was engaged in making a set of preliminary geological traverses through parts of the southern Shan States and Karenni, the main object being to cover as much ground as rapidly as possible in the time available.

Except for a brief tour by the late Mr. E. J. Jones in 1887, undertaken for economical investigations, the country was quite unknown in all details of its structure and stratigraphy. Mr. Middlemiss crossed the southern Shan States from Thazi as far east as Nongsewik (Long. 97° 45'). He then returned to Thamakan, and after working north for a short distance along the plateau, took a southerly direction to Loikaw in Karenni. From that point he carried a second cross-section through Karenni from the Salween river westwards to the plains again. The tour involved much hard and continuous marching.

The whole expanse of the country traversed was found to be an elevated plateau complicated by E.-W. crumplings of the strata and so giving rise to N.-S. hill ranges with longitudinal valleys between. The rocks naturally group themselves into N.-S. longitudinal strike-zones of different composition. Mr. Middlemiss recognizes the following: (1) a gneissic and metamorphic zone ronting the Irrawaddy plain; (2) a great limestone zone, occupying the greater part of the plateau proper; (3) a purple sandstone zone, occurring along certain lines in zone (2) and inlaid with it, as it were; and (4) a zone of very young (subrecent to uppermost Siwalik) conglomerates, sands and loams, hardly disturbed at all, and occupying in the form of long strips certain of the broad flowing valleys of the plateau.

The gneissic and metamorphic zone consist of mixed hornblendic and micaceous gneisses, resembling those of South India, with veins of intrusive granite, also of quartzites, black slates, and schistose slates.

The limestones are the most characteristic rock of the plateau, and are dark or light grey in colour, frequently much brecciated and interbanded with many shales and marls.

It is unfortunate that no recognizable fossils were found by Mr. Middlemiss except in the case of certain bands of shaly limestone and marls in the hills between Hopông and Mōng Pawn. In the latter (well-exposed along the Government cart-road) sufficiently good specimens were obtained to show that they are of middle Productus limestone age (permian). They are, therefore, probably a northern continuation of the Moulmein limestone.

The purple sandstone zone with its shales, coarse conglomerates, and coal beds, is thought to be younger than the neighbouring limestones. At the same time it has many points of resemblance to similar rocks east of Thibaw found by Messrs. La Touche and Datta in the northern Shan States.

Owing to dense jungle in places, to absence of good sections (except along the cart-road), and to the nature of massive limestone rocks, to weather into slopes of structureless blocks, Mr. Middlemiss found that his rapid survey does not warrant him in attempting to put in their normal order either the rock zones themselves, or their several component rock bands. It would at present be impossible to exhibit them in a generalized section showing the relative age and sequence of each; but it seems probable that their order in the section is not a simple one due to mere gentle undulation of the strata.

During his tour Mr. Middlemiss visited and examined some lead, silver, and copper mines near Bawzaing and Myinkyardo; some coal near Inwun, and lignite at several points in the Thamakan plateau. He also visited the "green-stone" tract on the Salween river near Namon, and found the stone (which is being collected as gems) to be green tourmaline with crystalline marble as matrix.

2. MADRAS PRESIDENCY.

MR. F. H. SMITH.
Ganjam.

During the season of 1899-1900 Mr. Smith was at work for five months during which time he reconnoitred an area of some 7,500 square miles, comprising the whole of the Ganjam district, except a small tract to the extreme south round Chicacole and Parlakimedi, which had already been mapped by the late Mr. Fedden of this Department.

Rocks.

The whole country is composed of two classes of rocks. By far the greater area is of crystalline igneous rock, into which bands of metamorphosed schist are folded. No unaltered sedimentary rocks are met with, but considerable areas are covered, and some of the hills are capped with laterite.

Crystalline igneous.

The foundation of the whole of the Ganjam district is a somewhat complex mass of rocks of igneous origin. By far the greater part consists of garnetiferous granitic rocks or leptynites, of every variety of texture, and of slightly varying composition, locally extremely crushed and foliated. Associated with these and interbanded with them is a series of pyroxene-bearing rocks—charnockites which pass gradually from acid forms to the more basic. The latter only occupy very limited areas, but the more acid pyroxene rocks, which are also garnetiferous, are found over extensive areas, passing by insensible gradations into the main leptynite mass.

Intrusive rocks of later age are not common, and ordinary trap-dykes are very rare, only a few small dykes of hornblende-diorite being met with in the hill tracts. In the Aska neighbourhood a fine-grained augite-biotite rock is found interbanded amongst the coarse crystalline rocks. It appears to have been originally intruded into the granitic rocks, and subsequently crushed and foliated with the surrounding rock.

Schist.

The bands of schist have been derived from ancient sedimentary rocks, probably ferruginous shaly sands and grits, which have been folded into the crystalline mass. In places it is seen to be only slightly altered, but usually the metamorphosed rock is now a well-defined quartz-garne schist, nearly always containing sillimanite, and occasionally minute grains of graphite.

Mineral limestone.

Associated with the schist, and apparently the result of the metamorphism of calcareous beds amongst the ancient sediments, are several interesting bands of crystalline limestone, which are full of accessory minerals. The latter frequently increase to such an extent that the calcite is of rare occurrence amongst the yellow-red garnets, green diopside, felspar, scapolite, quartz, apatite, sphene, and tourmaline. No trace of corundum or its purer forms of ruby or sapphire can be found amongst these minerals.

The junction between the schist and the granitic rocks is seldom seen, but when visible the schist passes over gradually into a more and more crystalline rock, until there is no well-defined boundary between the two series. It is remarkable that no intrusive granite is ever seen amongst the schist.

Economic geology.

The Ganjam district is not very promising from an economic point of view, and mica would seem to be the only mineral of possible value.

Gold.

Quartz reefs are practically absent throughout the district. Quartzose bands occur amongst the schists, but Mr. Smith was unable to find any trace of gold in any of them. None of the natives of Ganjam carry on gold-washing, and traces of the metal was met with in one stream only, namely, on the Mahendragiri Mountain.

Sapphire.

There has for some time been an idea that sapphires were to be found on Mahendragiri. In fact a few transparent and translucent sapphires of some value, said to come from the summit of Mahendragiri, were sent into the office of the Geological Survey for identification. On investigation it appears that a certain 'Kabul merchant' brought down a basketful of earth from a mound at the top of Mahendragiri and that on washing this earth he extracted the sapphires. I have examined the mountain which consists of coarse granitic rocks. There is no trace of corundum or sapphire in these, and nothing could be found in the remains of the mound which the merchant left. It is probable that the merchant took the stones up with him, or he may possibly have been in the possession of information of a buried treasure.

Mica.

For some years native physicians have bought mica dug from small pits in the Russellkonda neighbourhood. Several veins of course micaceous granite are found in the jungles a few miles to the south-west of that town. Mr. Smith had several pits sunk on these mica outcrops with the result that crystals of somewhat crushed and earthy mica were obtained up to 5 inches in diameter. The coarse micaceous rock, however, seems to be very inconstant and local in its development, and in the pits there was neither enough of the mother-rock, nor were the micacrystals large and pure enough to be of economic importance.

DR. T. L. WALKER.
The Hill Tracts of Vizagapatam.

The country surveyed comprised that part of the Vizagapatam district contained in the North-East quarter of Atlas sheet No. 93. Four rock groups were recognised, as follows :—

I. *Hypersthene-Garnet Granites and Gneisses* form the whole of the plateau of about 3,000 feet altitude. This rock formation is approximately bounded on the west by a line passing N.N.E. through Jeypore (E. Long. 82°38′, N. Lat. 18°51′). Only about 1,000 square miles of this rock formation were examined, though it is known to extend for long distances north, east, and south.

II. *The Crystalline Schists* occupy the level country to the west of the rocks of group I. To the north of N. Lat. 18°50′ these rocks are generally rather coarse biotite and hornblende gneisses, striking north-west, while to the south they are more varied, hornblende and biotite gneisses and schists, potstone and quartzites. The strike of these southern gneisses is generally north-east. About 1,200 square miles of crystalline schists were surveyed.

III. *Cuddapahs* (?).—Poorly exposed and of a small area these rocks occupy the western and north-western part of the country explored. Lithologically they are made up of purple and grey slates and shales, limestones semi-metamorphosed and lithographic, while near Tetulguma some well-defined conglomerates occur. At various points along the contact of the Cuddapahs (?) and the crystalline schists, hematite quartzites and quartzose rocks, which are possibly crushed conglomerates, occur. As similar rocks in India are at times auriferous, I crushed and panned several samples, but without finding even the colour of gold.—No fire assays have been made with a view to settling the question as to whether these rocks contain gold or not.

IV. *Diabase.*—In a much altered form occurs near Jeypore and also near Ramagiri, where it forms small hills whose geological relations are not known—it is probably the youngest of the four rock groups and possibly forms dykes.

Economic.—Iron is manufactured in many villages in the area occupied by the crystalline schists. The iron ores are generally poor,—hematite quartz rock, hematite and nodular limonite being the ores commonly used. Potstone is used to manufacture idols, while some of the limestones will be of value for lime and for ornamental purposes. The presence of rocks which may contain gold has already been referred to.

3. CENTRAL PROVINCES.

MR. P. N. BOSE.
Bastar State.

Part of a gap on the geological map of the Central Provinces comprising the greater part of the Bastar State was surveyed by Mr. Bose. The area is situated between Lat. 19° and 20°, and Long. 80° and 82°; besides this some gaps which this officer left in last season's maps north of Lat. 19° were also furnished. The area reconnoitred would be about 6,600 square miles. The greater portion of the ground —the entire country west of Long. 81°30′—is hilly (the hills occasionally rising to over 3,000 feet above the sea-level), jungle-clad, very sparsely populated, and but little cultivated.

The base rock is gneiss, usually of a granitoid character. Resting upon a denuded surface of it there occur—

I. A transitional series of a pronounced Dharwar facies with hematite qartzite, as its best developed and most prominent member forming straight, deeply notched, sharp-crested, precipitous ridges running along the strike. The rocks cover a very small area and are met with as fragmentary patches having been extensively intruded through by basic igneous rocks since their elevation. The strata are much disturbed; the strike, usually N. S., is, at places, twisted about, and the dip not seldom borders upon the vertical.

II. Rocks lithologically similar to those of the Chhattisgar basin and referable to the lower Vindhyan horizon. They cover almost the entire country between Lat. 18° 55′ and 19° 30′, and Long. 81° 35′ and 82° 5′. They consist of:—

(*a*) Basal sandstones, often more or less quartzitic and generally coarse, the bottom beds being usually massive and conglomeratic. They as well as the superincumbent shales (*b*) are nearly horizontal or roll about slightly. At Chiterkot (Lat. 19° 12′, Long. 81° 45′) there are exposed some 130 feet of them with interstratified lenticular bands of dark shales.

(*b*) Reddish, dirty grey, and buff shales (with intercalations of sandy beds) often passing into limestones. On the assumption of horizontality, their maximum thickness may be estimated at about 200 feet.

(*c*) Upper sandstones, quartzitic and fine grained. They are as a rule nearly horizontal, but, at one place, were noticed to be highly disturbed and faulted against the gneiss. They overlap the shales (*b*) on to the gneiss.

In the hill country west of Long. 81° 30′ there occur several considerable patches of excessively coarse, massive conglomerates overlaid by quartzitic sandstones and shales—an assemblage of rocks not unlike the lower Vindhyans mentioned above, but differing from these in being intimately intermingled with contemporaneous trappean rocks and in presenting features of greater disturbance.

Besides limestones of good quality in the lower Vindhyans, and rich and extensive deposits of iron-ore, especially in connection with the hematite-quartzite of the transitions, the only mineral of economic importance which was met is mica. Two veins of muscovite were discovered within very coarsely crystalline granitoid rock in the bed of the Baordhiy river south of Jungani (Lat. 19° 45′, Long. 81° 43′). The largest size of plates found measured about 5 inches in length. Being from the surface, however, they are much weathered, cloudy, and cracked. Four miles further south, nests and small veins of muscovite associated with vein quartz abound in coarse, much decomposed granitoid rock.

4. PUNJAB.

DR. F. NOETLING.
Salt Range.

The relations of the upper Palaeozoic to the triassic beds of the Salt Range is of such importance and of such close bearing upon Indian geology generally that it became desirable to revise some of the work done already by Messrs. Wynne and Waagen in past years and to supplement it by further researches. The late Professor Waagen, who had described the fossils collected in 1872, had come to the conclusion that not only a great gap existed in the sequence between the permian and triassic beds, but that there also existed a great difference between the fauna of the Salt Range and that of the Himalayan trias. According to Professor Waagen this difference is chiefly proved by the absence of the genus *Otoceras*, which he stated positively does not occur in the Salt Range.

Dr. Noetling had frequently expressed his doubt about the correctness of this view. He stated that as far as he could judge from a flying visit paid to one of the triassic outcrops in the Salt Range, there existed a perfect passage between the topmost permian beds and those which were considered to be of triassic age, and consequently the *Octoceras* beds which form in the Himalayas the base of the triassics must, in his opinion, be represented in one way or another. Dr. Noetling felt inclined to consider some unfossiliferous beds at the base of the triassics in the Salt Range as the equivalents of the *Octoceras* beds.

In order to decide this question Dr. Noetling was deputed to the Salt Range, where he examined some of the most important sections near Virgal and Chidru, with the result that it was proved that his supposition of the existence of a gradual passage between the permian and the triassic beds was fully confirmed. Professor Waagen's hypothesis of a break in the sequence fell to the ground as it was plainly and flatly contradicted by actual facts. Shortly afterwards Dr. Noetling reported that he had discovered *Otoceras sp.* in several specimens, but to his greatest surprise not at the base of the Ceratite formation as he expected, but right in the middle of the Ceratite marl. Thus proof was given of the most important fact that not only did the genus *Otoceras* exist in the triassic beds of the Salt Range, but that the whole of the Ceratite marl to which a much higher position was attributed by Professor Waagen must be considered to be the equivalent of the *Otoceras* beds of the Salt Range.[1]

Dr. Noetling examined also the permian system, and he discovered that the main layer of *Xenodiscus carbonarius*, Waagen, was not, as supposed by Professor Waagen, high up in the upper Productus limestone, but about 500 feet lower down, near the top of the middle Productus limestone. This is also a very important discovery, inasmuch as it will materially help towards the correlation of certain beds in the Himalayas. Dr. Noetling holds that the trias (ceratite beds) of the Salt Range and the Productus limestone must be considered as subdivisions only of one and the same series, because the gradual passage from the lower beds full of palæozoic brachiopoda to the upper beds in which the ammonites occur makes a stratigraphical subdivision into two great periods an absolute impossibility. The following table shows the sequence of beds according to Dr. Noetling's view, in descending order :—

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[1] It is necessary to state that the species of *Otoceras* referred to differs from the Himalayan forms of *Otoceras* in some characteristic details, if indeed it can be referred to this genus. It is certain, however, that it is closely allied to it. (Director.)

	German.	Salt Range.		
Marine Neo-Dyas.	Lower Trias.	Baktrian.	Upper ceratite limestone	Zone of *Stephanites superbus*, Waagen.
		Sindian.	Ceratite marl.	Zone of *Flemingites flemingianus*, Waagen. Zone of *Koninckites volutus*, Waagen. Oboceras-beds. Zone of *Prionolobus rotundatus*, Waagen.
	Zechstein.		Lower ceratite limestone.	Zone of *Celtites spec.*
			Upper productus limestone.	Zone of *Euphemus indicus*, Waagen. Zone of *Derbyia hemisphaerica*, Waagen. Zone of *Productus lineatus*, Waagen.
			Middle productus limestone.	Zone of *Xenodiscus carbonarius*, Waagen. Zone of *Lyttonia nobilis*, Waagen. Zone of *Fusulina kattaensis*, Waagen.
Marine palæo-Dyas.			Lower productus limestone.	Zone of *Spirifer marcoui*, Waagen.
Glacial palæo-Dyas.	Rothliegendes.			Lavender Clay unfossiliferous.
		Dravidian.	Speckled sandstone.	Speckled sandstone. Bivalve beds. Zone of *Conularia laevigata*, Morris.
				Boulder bed.

5. HIMALAYAS.

KUMAON.
Messrs. LaTouche, Smith, and Walker.

The description of the large Himalayan collections, especially of the upper trias, had made it most desirable that certain localities in the Kumaon Himalayas should be re-visited, and accordingly Mr. LaTouche was deputed to the upper Lissar valley, whilst Mr. Smith was charged with the detailed work in Byans and the Kuti Yangti valley. Dr. Walker was sent to the Chitichun "Klippen" northwest of the Milam passes. The season proved an unusually unfavourable one and severe weather with snowfalls impeded the movement of the three parties considerably. Dr. Walker had to close his field-work very early owing to severe indisposition. However, the results are very commendable and very good collections have been made by these three officers, which will be worked out in due course.

SPITI.
Mr. H. H. Hayden and Dr. A. von Krafft.

Survey work was again taken in hand in Spiti during the hot season of 1899. Mr. Hayden and Dr. von Krafft were posted to that part of the Himalayas and they reached the Spiti valley on the 22nd May 1899. The early part of the season was devoted to joint studies on the lower trias near Muth and a large collection of fossils was made in these beds. Later on the work was divided between these two officers, and each has given a progress report on his share of the survey, which is practically nearly finished, only a few months work remaining to bring the whole up to a certain degree of completeness.

With the exception of some almost inaccessible parts of the snowy range between Spiti and Hundes, the whole of the former district has been mapped and the survey carried through Kanaur and Hundes into Rupshu.

The whole sequence of beds has been examined in as great detail as the time available would permit, and collections have been made from several fossiliferous horizons. The results show that all the systems from upper cambrian to cretaceous are probably represented in Spiti and Bashahr. Considerable attention was paid to the upper trias, several interesting discoveries having been made with reference to that system, which has been found to be more complete than has hitherto been supposed to be the case in the Himalayas. Certain sections which have as yet been only cursorily examined, promise to yield important results, chiefly with regard to the extent of the permian and carboniferous systems, and when these have been worked out it is hoped that it will be possible to publish a fairly complete memoir on this area.

The following are a few of the more important results obtained by the Spiti party :—

(1) A *trilobite* fauna of upper Cambrian age has been found in the Parahio valley.

(2) An important unconformity has been proved to exist between the Cambrian and Silurian systems.

(3) Upper silurian fossils have been found in Spiti and Bashahr.

(4) A great system of limestones overlain by shales and quartzites—including beds of upper carboniferous and permian age—has been found near Lio in Bashahr. This system is not known to attain such full development in any other part of the Himalayas.

(5) Large collections, including many new forms, have been made from the lower trias beds and have been worked out by Dr. Krafft.

(6) The muschelkalk, from which several forms new to the Himalayas have been obtained, has been found to extend both upwards and downwards further than had hitherto been suspected. The lowest bed in which fossils occur contains a very interesting ammonite fauna.

(7) The upper muschelkalk passes up perfectly gradually into beds of ladinic age, with *Daonella lommeli*, Wiss., and there is no trace in Spiti of a break between the muschelkalk and the upper carnic stage.

(8) No break of any kind has been found in the triassic beds, but there appears to be a perfectly gradual passage from lowest trias to jurassic.

(9) The upper trias beds are of great thickness and contain numerous fossiliferous horizons, many of which can be identified with those found by Mr. Griesbach and Dr. Diener in the Central Himalayas.

In the following table will be found a rough classification of the sedimentary rocks of Spiti and Bashahr :—

Spiti.	Fossil contents.	*Other parts of the Himalayas.*	*Europe.*
Black (Spiti) shales.	Upper jurassic *ammonites.*	Spiti shales.	Upper jurassic.
Grey and black earthy limestones, passing up gradually into the Spiti shales.	*Stephanoceras* cf. *coronato,* Brag. *Spiriferina* cf. *obtusæ,* Opp. (?)*Spirigera nœtlingii,* Bittn.		Dogger. (?)Lias. (?)RHÆTIC.
	Megalodon ladakhensis, Bittn.	Dachstein Kalk in part.	Upper trias.
White and brown quartzites, black shales, and hard grey limestones.	*Aulacothyris joharensis,* Bittn. *Lima cumanica,* Bittn. *Spiriferina griesbachi,* Bittn.		
Brown-weathering, sandy, and shaly limestone, sandstone and dolomite.	*Spiriferina griesbachi,* Bittn. *Anodontophora griesbachi,* Bittn. *Aulocothyris joharensis,* Bittn. *Distichites,* n. sp. *Monotis salinaria,* Br. *Spirigera dieneri,* Bittn.	"Sagenites beds."	
Coral limestone.	*Spiriferina griesbachi,* Bittn. *Rhynchonella bambanagensis,* Bittn.	"Limestone with *Spiriferina griesbachi.*"	
Brown-weathering, sandy, and shaly limestones; sandstones and shales, with black splintery limestones.	*Paratibetites tornquisti,* E. v. Mojs. var. *Juvavites* aff. *ehrlichi,* v. Hau.	"Halorites beds"	
	(?)*Hauerites n.f. ind.* E. v. Mojs *Paratibetites* aff. *tornquisti* E. v. Mojs.	"Hauerites beds."	
Dolomitic limestone.			

Spiti.	Fossil contents.	*Other parts of the Himalayas.*	*Europe.*
Splintery limestones, grey shaly limestones, and calcareous shales.	*Tropites* cf. *subbullato*, E. v. Mojs. *Tropites* aff. *discobullato*, E. v. Mojs. *Clydonautilus griesbachi*, E. v. Mojs.	"Daonella beds"	
Grey, earthy shales, with shaly limestone partings.	*Spiriferina shalshalensis*, Bittn. *Rhynchonella lankana*, Bittn. *Joannites cymbiformis*, W. *Trachyceras* cf. *aonoides*, E. v. Mojs.		
Hard, dark, splintery limestone with shaly limestone intercalated.	*Halobia* cf. *comatæ*, Bittn. ,, cf. *fascigeræ*, Bittn.		
	Daonalla lommoli, Wiss.		
Black shaly limestones.	*Daonella indica*, Bittn. ,, *lommeli*, Wiss. *Gymnites ecki*, E. v. Mojs. *Trachyceras ladinum*, E. v. Mojs. *Proarcestes bicinctus*, E. v. Mojs. *Ptychites gerardi*, Blanf.		Ladinic stage.
Grey and black concretionary limestones with thin shaly partings.	*Ptychites rugifer*, Opp. *Ceratites thuilleri*, Opp. *Spiriferina stracheyi*, Salt. *Ceratites subrobustus*, E. v. Mojs. *Sibirites prahlada*, Dien. *Danubites kansa*, Dien.	Upper. Lower. Muschelkalk.	Muschelkalk.
Nodular limestone.	Very poor in fossils.	Age uncertain.	
Grey, earthy, and concretionary limestones and shales.	*Hedenstræmia mojsisovicsi*, Dien. *Danubites nivalis*, Dien.	"Subrobustus beds," Diener.	

Spiti.	Fossil contents.	*Other parts of the Himalayas.*	*Europe.*	
Black limestones and shales.	*Proptychites ammonoides*, Waag. *Miikoceras*, n. sp. *Ophiceras sakuntala*, Dien.	Otoceras beds. Griesbach.	Lower trias.	
Black shales.	*Xenodiscus carbonarius*, Waag. *Cyclolobus oldhami*, Waag. *Brachiopoda* of the "Productus shales."	Productus shales.	CARBONIFEROUS AND PERMIAN.	
Calcareous sandstone or sandy limestone, underlain by grits and conglomerates.	*Spirifer musakheylensis*, Dav. *Athyris gerardi*, Dien. *Productus purdoni*, Dav. *Martinia glabra*, Mart.			
Alternating beds of shale and quartzite.	*Bryozoa* (*Fenestella*, etc.) badly-preserved *brachiopoda.*	(?) "Zewán beds" of Kashmir.		
Limestones, slates, and quartzites.	*Phillipsia* cf. *cliffordi*, Woodw. *Rhynchonella* cf. *pleurodon*, Phill. *Derbyia* sp. *Syringothyris* sp.			
Grey limestone, often oolitic and crinoidal.	*Productus* sp. *Athyris* sp. *Syringothyris* cf. *cuspidata*, Mart " cf. *distans*, Sow.	Upper carboniferous, 8a, Mem. G. S. I., Vol. XXIII. Griesbach.		
White quartzite.	Apparently unfossiliferous.	Carboniferous.	(?)DEVONIAN.	
Grey siliceous limestone, weathering brownish red.	Fragments of *crinoids* and *brachiopods.*	"Red crinoid limestone." Griesbach		
Limestones, marls, and slates.	*Halysites catenularia*, Luck. *Calymene* sp.		Upper.	SILURIAN.
Red gritty quartzite, underlain by conglomerates.	Apparently unfossiliferous.		(?)Lower.	

Spiti.	Fossil contents.	*Other parts of the Himalayas.*		*Europe.*	
Slates and quartzites, with thin bands of dolomite.	*Ptychoparia* sp. *Olenus* sp. and other upper Cambrian trilobites.			Upper.	CAMBRIAN.
Red quartz-schists, slates, and carbonaceous shales.		Upper.	Haimanta.		
Quartzites and slates.		Middle.			

6.—SIND.

DR. FRITZ NOETLING.
MR. E. VREDENBURG.

As a considerable difference of opinion existed with regard to the development of the tertiaries in Baluchistan and Sind, Dr. Noetling was deputed during the second-half of the season to Sind, where he was later on joined by Mr. Vredenburg.

Dr. Noetling thoroughly examined the northern part of the Laki range, while Mr. Vredenburg studied the country in the neighbourhood of Ranikot. Later on the party examined the country between Jhirrak and Meting. Though only a comparatively short time could be devoted to these researches the results obtained are very important, and the view which Dr. Noetling held with regard to the middle eocene of Baluchistan—namely, as being an equivalent of the Ranikot group—has been fully proved to be correct. Dr. Noetling and Mr. Vredenburg brought together a splendid collection of fossils, and though a considerable time will elapse before these will be described, the systematic researches of these officers have shed quite a new light on the stratigraphy of Sind. As the eocene was chiefly examined, these new observations concern of course that sub-division of the tertiary system only, and according to Dr. Noetling the sequence of the eocene is as follows in descending order:—

NARI-GROUP .	17 Zone of *Cerithium*, spec. nov. 16 Zone of *Eupatagus rostatus*, d'Arch. 15 Zone of *Echinolampas discoideus*, Dup.

RANIKOT-GROUP	14 Khirthar limestone.
	13 Zone of *Anomia*, spec. nov.
	12 Zone of *Cardita*, spec. nov
	11 Zone of *Pugnellus*, spec. nov.
	10 Zone of *Nummulites granulosus*.
LOWER EOCENE	9 *Alveolina* limestone.
	8 Zone of *Macropneustes speciosus*, Dup.
UPPER CRETACEOUS	7 Zone of Gen. nov. spec nov. (*Rostellaria*, spec. Bland.)
	6 Unfossiliferous sandstone.
	5 Zone of *Ostrea lingua* (?)
	4 Basalt.
	3 Zone of *Turritella*, spec. nov.
	2 Zone of *Cardita beaumonti*.
	1 Nodular limestone.

The above sequence differs considerably from that first established by Dr. Blanford. In fact it appears that Dr. Blanford mapped as Khirthar limestone (upper eocene) a considerable part of the limestone which in the above sequence appears as No. 9 below the Ranikot-group.

If we consider the limestone No. 9, which Dr. Noetling calls alveolina limestone, to be an equivalent of my alveolina limestone of Baluchistan, the sub-division of the eocene both in Sind and Baluchistan is precisely alike, namely:—

SIND.	BALUCHISTAN.
Khirthar limestone.	Upper eocene limestone (Spintangi, Oldham).
Ranikot-group.	Middle eocene shales.
Alveolina limestone.	Lower eocene limestone (alveolina limestone).

7.—BALUCHISTAN.

MR. E. VREDENBURG.

After returning from the Seistan Mission, which Mr. Vredenburg accompanied during the season 1898 to 1899 (see last year's General Report, pages 63, etc.), this officer was deputed during the hot months of last year to the Kojak range and the Toba plateau in Baluchistan to study the peculiar Kojak formation in greater detail and to compare it with the south-western extension of it, which he had already met with during his Seistan tour. The full report on this survey, it is hoped, will appear when some gaps in the geological maps east of this area are filled in and when it will be possible to bring out a volume descriptive of the geology of Baluchistan and compiled by the several observers who have worked out the details of it. Regarding the Kojak range Mr. Vredenburg writes in his official diary:—" * * * I had stated that the broad range east of Nushki, consisting of many parallel ridges, which is the southern continuation of the Kojak or Khwaja Amran, consists of two different systems of strata: the western margin of highly cleaved slates with narrow beds of sandstone, and with much vein-quartz, I took at first to be some palæozoic rock; afterwards absolutely similar rocks were found to be highly metamorphosed eocene. All the eastern portion of the range consists of sandstones and shales in which I found no fossils; they are much folded, but neither cleaved nor metamorphosed like the rocks along the western margin and contain no quartz-veins. I met with similar rocks, always unfossiliferous in several places in the desert, and have several times altered by opinion as to their age, owing to the disconnected and unmethodical manner in which this season's work was unavoidably performed. In the present instance a careful examination of the section from Nushki to Kishingi showed that the one type of rock passes quite gradually into the other; the slates along the western margin are merely metamorphosed representations of the shales which constitute the eastern ridges. A few bands of limestone with crushed fossils occur indifferently in the slates and in the unaltered shales. On closer inspection it was found that the calcite veins common in the unmetamorphosed shales exist in the slates as well; the quartz-veins are restricted to the slates and are a result of metamorphism. In some portions of the Kharan hills, where the rocks were locally less disturbed than usual, they assumed the same facies as these shales and sandstones, and in this case a few fossiliferous beds contained *nummulites*. It may, therefore, be regarded as established that these rocks are eocene; they owe their peculiar facies to a greater development of the arenaceous element or a dwindling of the limestone; they would correspond probably to the Ghazij division[1] of Mr. Oldham. Such a conclusion simplifies the interpretation of all the regions where these rocks have been observed. The same rocks are the only ones I have met with, so far, in the Pishin district. I have examined nearly all the valleys that descend from the Toba plateau to the north-west, north, and north-east of Pishin. The rocks are quite similar to those met with between Nushki and Kardagap; the strata are generally somewhat gently undulating, but, just as in the Nushki region, the folds become sharper and slaty cleavage sets in as the Kojak range (or its northern continuation) is approached. * * At the time of my first visit the range east of Kardagap (southern continuation of the Ghaziabad range) was crossed along the 'Kurd Barak' pass, where the rocks were almost entirely concealed. On the present occasion I crossed it further south and was able to observe that it consists almost entirely of massive nummulitic limestone with some very subordinate shale bands. It is flanked by siwaliks on either side."

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[1] Middle eocene, Griesbach.

Part III.

Progress Reports of Officers of the Geological Survey of India for the year 1899-1900.

Note *on the* Auriferous reefs of South and South-East Wainád, *by* H. H. HAYDEN, B.A., B.E., *Officiating Deputy Superintendent, Geological Survey of India.*

Prospects of gold mining in Waináad.

During the past few months an examination, on a small scale, has been made of the more important reefs in South and South-East Wainád, the general results of which tend to show that the majority of the reefs are probably too poor in gold to offer any prospects of remunerative working; yet it is possible that one or two may prove sufficiently rich to justify mining operations, provided these are carried on judiciously and under strictly expert supervision. This opinion, however, is given with considerable diffidence, for the scale on which the examination has been carried out was so small, as to render it a matter of extreme difficulty to arrive at any reliable conclusions as to the average value of a given reef. This difficulty is intensified by the fact that the gold appears to be most capriciously distributed. Till, therefore, trials on a considerably larger scale have been made, any recommendation as to the advisability or otherwise of the resumption of mining operations would seem hardly justifiable. Many of the reefs, however, have yielded consistently poor results, and of these it may be safely assumed that they are not likely to be worth working: but a few have given results ranging from over an ounce to a few grains of gold per ton of ore, and these results should warrant the undertaking of more extensive investigations.

Reefs.

Auriferous reefs occur both in South and South-East Wainád.[1] In the latter area, however, they are by far the more numerous, and are to be found chiefly in the neighbourhood of Dévála and Pandalur. Most of these reefs

[1] King, Rec. G. S. I., Vol. VIII, 2 (1875).
" " " Vol. XI, 3 (1878).
Brough Smyth: "The Gold Mines of the South-East Wainád and Carcoor Ghát." (1880.)

have been re-examined, but in the present short note it will be sufficient to mention only those which have yielded an appreciable amount of gold.

Skull reef.

The most important of those near Dévála are found on the edge of the ghât between Sulimalai (Hill) and Nadugáni, and include those formerly known as the Skull, Bear, Cavern, Kurambar, and Hamlin's reefs. Of these the Skull reef is the only one which has yielded more than a small percentage of gold. It was worked to some extent by the Alpha Gold Mining Company, and numerous drives and adits are still to be seen, though in most cases, owing to the heavy rainfall on the edge of the ghât, they are more or less blocked up by the falling in of the roof.

The reef is composed of white quartz containing highly pyritous bands of varying thickness, and it is in these bands that most of the gold is found, the white non-ferruginous quartz being almost barren. The casing, which is formed of a more or less brecciated mass of quartz, talcose, and schist, and decomposed iron ores (now chiefly limonite or hæmatite), is also frequently rich, but its thickness is usually only a few inches.

The following list contains the results of a few tests made on the Skull reef:—

Number.	Locality.	Amount crushed.	Amount of gold to ton of ore.	Portion of reef represented.
			oz. dwt. gr.	
1	Kurambar tunnel S. E. end.	600lbs.	0 1 13	Whole reef.
2	Open quarry west of Alpha Company's bungalow.	93lbs.	0 0 18·5	Ditto.
3	No. 9 adit . .	7lbs.*	0 13 1	Ferruginous portion of reef, 2 feet thick.
4	Ditto . .	6lbs.*	0 11 16	Ditto.
5	Ditto . .	7lbs.*	0 3 8	Whole reef.
6	No. 7 adit . .	7lbs.*	Traces.	Ditto.
7	Ditto . .	6lbs.*	1 7 6	Upper part of reef (one feet six inches thick) and casing.
8	Ditto . .	7lbs.*	1 0 0	
9	Ditto . .	5lbs.*	4·16 dwts.	Ditto.
10	Ditto . .	7lbs.*	8·93 „	Ditto.

* Taken by sampling from a mass of about 200 lbs.

Bear reef.

The results obtained from the Bear, Kurambar, and Hamlin's reefs were all small, the highest being from the Kurambar reef, *viz.*, 4·66 dwts. to the ton. None of these reefs have been exploited to any extent by the Gold Mining Companies, but the Bear reef was worked by the old native miners, who furrowed out small tortuous passages along the reef in order, apparently, to get at the casing. A small adit of about 30 feet in length represents the only mining done by Europeans. In this adit is a small leader—six inches thick—of highly pyritous ore, which yielded gold at the rate of 10 dwts. to the ton.

Hamlin's reef.

Hamlin's reef was formerly mined to some extent, but almost all the old workings have fallen in. One adit is still open, but the reef is not seen in it, a leader only having been opened up. This leader is ten inches in thickness and contains visible gold. Seven lbs. of quartz from it was taken out of a mass of about 150lbs. and yielded gold at the rate of two ounces to the ton: the sample treated showed no visible gold.

Kurambar reef.

The Kurambar reef has also been opened up by a small adit. Two samples of quartz taken from this adit gave—

1. Trace of gold: from 7lbs. of ore.
2. 4·66 dwts. to the ton.

The results obtained from most of the other reefs in the neighbourhood of Dévála were poor, usually about 1 dwt. or less to the ton.

Richmond.

Of the reefs in the neighbourhood of Pandalur, those on the Richmond and Phœnix Estates have been mined; the former, which is seen near the Richmond tea-factory, has been opened up by an adit about 300 feet long, from which small drives have been run along the reef, which is here about four feet thick and carries a band of highly pyritous ore: the thickness of this band is about one foot. Two samples treated gave respectively 1 oz. 7 dwts. 4·8 grs., and 5½ dwts. of gold to the ton of ore.

Phœnix.

The largest mine in South-East Wainád is that on the Phœnix Estate. The reef has been worked on three different levels, and the mine while under expert management is said to have paid expenses, work having eventually been stopped by the orders of the Government of India, in consequence of the frequency of accidents which resulted in the death of several native miners. The ore, however, appears to be of quite a low grade, yielding only about 2 dwts. of gold to the ton. The gold is very finely divided, but appears to be distributed fairly regularly throughout the greater part of the reef, though richer bands with much pyrites occur in places. The reef, which has an average thickness of about four feet, has been proved over a considerable area.

Geology of South-East Wainád.

The rocks of South and South-East Wainád fall roughly into seven classes, *vis* —

1. The charnockite series. (Acid, intermediate and basic varieties.)
2. Hornblendic rocks, associated with the charnockites.
3. Biotite gneiss.
4. Biotite granite.
5. Pegmatite veins.
6. Younger basic dykes.
7. Quartz reefs.

Charnockite.

The *charnockites* form the mass of the Nilgirís bordering on Wainád, and are found at various points intrusive in the biotite gneiss, forming in fact most of the more striking hill masses in South and South-East Wainád. On their borders, and apparently connected with them, occurs a series of *hornblendic rocks*, often resembling old basic dykes, now represented by pure hornblende rocks or epidiorites; these too contribute some important features to the landscape.

Hornblendic rock.

Biotite gneiss.

The *biotite gneiss* is everywhere soft and highly decomposed. In South-East Wainád it is usually more or less hornblendic, probably owing to the numerous intrusions of charnockite. It is, as a rule, the country rock in which the quartz reefs occur.

Biotite granite.

Biotite granite, strongly resembling the "dome gneiss" of Hazáribagh, occurs at Sultan's Battery and Kalpata Hill, and is probably connected with the numerous veins of pegmatite found throughout Wainád.

Pegmatite.

The *pegmatite* veins which appear to run more or less at right angles to the quartz reefs, *i.e.*, practically parallel to the strike of foliations of the country rock, are composed of great masses of quartz and felspar with fairly large crystals of mica: the only other mineral hitherto indentified in them being garnet, which is not common.

Mica.

The mica, which is "ruby" mica, is of excellent quality, occurs in considerable masses, and crystals of over 2 feet × 2 feet have been found. Mining is being begun on a small scale, but at the time of my visit amounted to little more than a few scratchings of the surface: but there is good reason to hope that before long mica mining will prove an important and prosperous industry in Wainád.

Dykes.

The *younger basic dykes* have been found only in two localities in South Wainád, and consist of fairly fresh rocks approaching dolerite in composition.

"Country" rock.

In most cases the country rock in which the quartz reefs occur is biotite or hornblendic gneiss; it is always decomposed to a depth of a hundred feet or more, and is so soft that it can be readily dug out with a pick, and blasting is almost unnecessary. Tunnelling is therefore easy and rapid, but this advantage is considerably discounted by the fact that the softness of the rock necessarily involves very extensive timbering.

Facilities for mining.

Most of the reefs are found cropping out on the edges of the ghâts and can therefore be worked down to a depth of several hundred feet by means of adits run in from the hill sides.

Timber.

Timber is no longer available in the immediate neighbourhood of the veins, but could be obtained in large quantities from the forests at the foot of the ghâts.

Water.

With the exception of that on Richmond Estate, all the reefs mentioned above are situated near perennial streams, and water-power sufficient to run a considerable amount of machinery would be obtainable; this would of course involve the construction of dams.

Labour.

Labour, at the rate of four annas per diem, is said to be available in large quantities in the neighbouring taluk (Ernád taluk of Malabar).

Roads.

Much of the road from the nearest port and Railway station, Calicut, is in a hopeless state of disrepair and is said to be impassable for wheeled transport during the monsoon. The worst portions, however, are being taken over by the Government and will probably in the course of a year or so be restored to their former excellent condition.

Land tenure.

So much for the *natural* conditions, which bear on the question of the success or otherwise of mining operations in Wainád. One point, however, still remains to be considered, *viz.*, the question of land tenure, and of such vital importance is this, that it has seemed advisable, even in the present short note, to enter into the matter at some length.

In South-East Wainád, owners of all lands may be divided roughly into two classes, *viz.*—

A. The Government of India.

B. Owners other than the Government of India. An owner of this latter class is termed a "private jaumi."

In the first case the Government of India is the absolute owner. In the second case, the lands are held by the owner or *jaumi* subject to a tax or rent known as *assessment.*

(1) Lands included under class A, *i.e.*, lands of which the Government of India is the jaumi, when taken on lease, are subject to the following charges:

(*a*) Assessment, paid on the whole or only a portion of the land, at rates varying from six pies to two rupees per acre according to the quality of the land.

(*b*) *Jauma-bogum* or rent, usually at the rate of eight annas per acre.

The payment of the above charge is made of course to the Government of India.

(2) Lands held on lease from a private jaumi (class B) are also subject to similar charges, *viz.*—

(*a*) *Assessment,* at the same rates as above, paid to the Government of India, by the *occupier,* whether he be the owner (jaumi) or a tenant ("patadar").

(*b*) *Jauma-bogum* or rent, paid by the tenant or lessee to the private jaumi *at such rates as may be fixed by private arrangement between the parties concerned.*

All lands held for purposes of gold mining, whether held directly under the Government of India, or on lease from a private jaumi, are subject to a *Government* royalty of 7½ per cent. of each year's net profits.

In the case therefore of lands of which the Government of India is the jaumi, the *maximum* charges to which they will be subject may be estimated at about R 2-8 per acre, *plus* a royalty of 7½ per cent. on the net profits of mining operations, while, on the other hand, lands held under a private jaumi will still be subject to assessment (at a *maximum* of R2 per acre) and a royalty of 7½ per cent. on net profits of mining, and, in *addition,* rents or other charges (such as royalties, etc.,) at a rate to be arranged between the private jaumi and the intending lessee, and as most of the auriferous lands of South-East Wainád belong to large native landed proprietors, who naturally wish to make the terms as profitable to themselves as possible, there is some danger that they may refuse to grant leases except on prohibitive terms, thereby putting a veto on all mining till they can be induced to accept more reasonable offers. This danger indeed seems imminent at the present time and if allowed to continue will seriously affect the new and promising mica-mining industry.

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Preliminary Report *on the* Auriferous tract *in the* Wuntho District *in* Burma, *by* G. A. STONIER, A.R.S.M., F.G.S., *Mining Specialist, Geological Survey of India.*

During the field-season of 1899 to 1900 I was engaged in investigating the conditions under which minerals (particularly gold) occur in the district bounded by Banmauk on the north, Kawlin on the south, Seu on the east and Pinlebu on the west. I have done as much original prospecting as was possible during the time at my disposal, but the work was seriously impeded by the want of skilled labour with which to carry out ordinary methods of prospecting such as are adopted in America and Australia.

During the month of February I was employed in detailed prospecting work, a close study of the Choukpazat lode (underground and on the surface), and the survey of several traverses which were necessary on account of the incomplete character of the plans supplied to me.

Choukpazat.

The Choukpazat reef was discovered by Burmans and the outcrop was worked by them to a depth of 8 or 10 feet. Mr. C. M. P. Wright, who was prospecting in the neighbourhood in 1894, came to these old excavations and after a series of tests, he discovered the shoot of gold and commenced to sink upon the reef. To illustrate the difficulties connected with the preliminary proceedings, it may be mentioned that, at one time, the strike of the vein was believed to be north and south, and it was only by a considerable amount of work that the direction was found to be E. 30° N., and the underlie to be S. 30° E. at 62°. The vein has been proved to a depth of 420 feet, though all the slopes are above the 310 feet level. The length of the vein is 240 feet and the richest part of the deposit has been found midway between the north-eastern and south-western boundaries. The thickness varies from two inches to ten feet and averages about three feet six inches. The veinstone contains 14 dwts. of gold to the ton of stone and consists chiefly of a compact quartz, generally white in color, but in places banded with black streaks which are roughly parallel with the walls of the vein and show very clearly by candle-light in the mine. The quartz varies considerably in character and below the 310 feet level is associated with calcite : in places it is devoid of an accompanying mineral, but in other parts of the vein there is so much galeña, copper pyrites and iron pyrites present that the ore has the appearance of a complex copper-ore.

The free gold is fine, irregular in occurrence and is most abundant where altaite (telluride of lead, tin-white in color) is present: it is frequently associated with copper pyrites and is visible at the 310 feet level. Unless the character of the stone be known, a heap of milling ore may be examined without a single "specimen" being discovered: under the circumstances it is needless to add that miners do not steal specimens.

The footwall and hanging-wall are sometimes well defined and the latter is polished and occasionally striated. "Horses" (*i e.*, included country) are of common occurrence and have been found to carry payable gold. "Breaks" are met with in the footwall and less frequently in the hanging-wall.

The vein is cut off on the south-western end by intrusive felsite(?), a description of which must await microscopic examination. The vein thins as it approaches this rock and passes into a small mullocky vein at the junction of the intrusive and intruded rocks. At the north-eastern end the lodestuff appears to be cut off at the outcrop by a fault, but in the Main Adit (94 feet level) there is no sign of a fault, and the vein gradually thins until it cannot be traced even as a division-plane traversing the country. Below the Main Adit the levels have not been extended in a north-easterly direction from the main shaft, which latter is wholly in ore. It is of considerable importance that the mine should be proved, not only in depth, but also in the horizontal direction indicated.

Attempts to trace the extension of the view, beyond the auriferous shoots, have failed both in a north-easterly and south-westerly direction.

Specimens sent by Mr. Wright from the hanging-wall at the 310 feet level have been examined by Messrs. Middlemiss and Holland, both of whom report it to be a "pyroxene rock." I think that both the hanging-wall and footwall belong to the series in which are the tuffs, a series largely developed in the district. The rocks have the general appearance of sediments, although it was impossible to obtain evidence of their sedimentary origin—the sections are poor. In some respects the rocks resemble a thick series of tuffs, breccias, etc., of devonian age which I discovered at Bingera (New South Wales), and in the absence of palæontological evidence I should consider the Choukpazat rocks to be as old as the Australian beds referred to.

Within 75 yards of the outcrop of the Choukpazat vein, intrusive diorite has been found: a specimen, selected by me, has been examined microscopically by Mr. T. H. Holland. This rock can be traced in a northerly direction along the Choukpazat Stream as it is found at intervals for a distance of one mile.

A mass of diorite occurs at Shintha, four miles north of Choukpazat village, and appears to be on the same line of disturbance. Taking into consideration the wavy line of junction, the occasional (perhaps even frequent) alteration of the tuffs, at the junction, and the thin tongues of diorite penetrating the tuffs, there is no room for doubt that the diorite is of later age and intrusive into the tuffs.

The evidence for the relation of the felsite to the tuffs is not as satisfactory but is, I think, sufficient to establish the intrusive character of the felsite. At about one mile south of Choukpazat village a good section is seen: porcellanites rest vertically on felsite, which latter is indistinctly schistose in places.

The mode of occurrence of the quartz and its association with calcite show that the quartz, occurring in the vein, is not interbedded but is younger than the enclosing rocks and has been deposited from solution. The question will be more fully dealt with in a subsequent report.

Half a mile in a northerly direction, a quartz reef (parallel to, and in the same country as the Choukpazat vein) has been discovered but has not been prospected.

Nine hundred yards to the north-north-east two quartz veins have been found. One, known as the Peregrine, has been cut by an adit 136 feet long and a level is being driven N. 10° W. in a direction along the vein which varies from 12 to 16 inches in thickness: a quantity of ore has been raised and awaits treatment. Seventy yards west-north-west of the Peregrine adit, a vein known as the Masheeboo has been cut in a level driven 24 feet S. 51° E. and N. 51° W. from an adit ninety-five feet long. The reef is seen only in the western end of the level and varies from an inch to a foot in thickness. A parcel of ore is being raised.

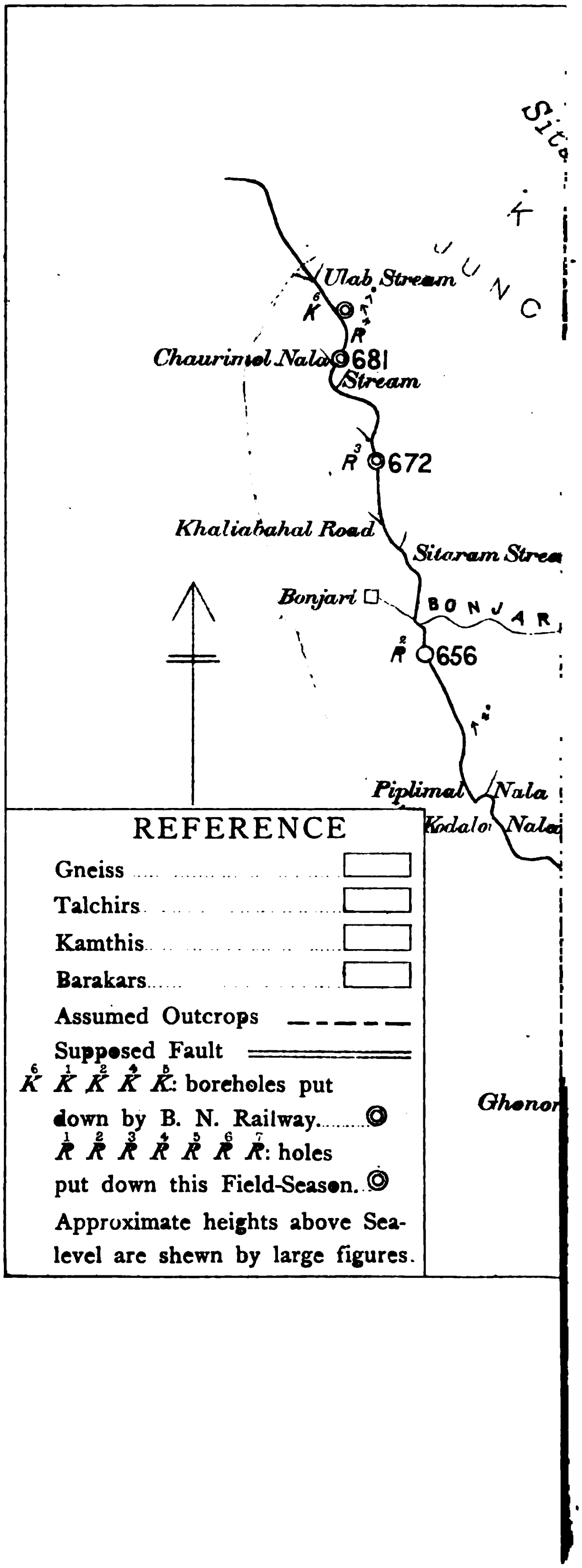
The mill is situated on the Nevalabo Choung, one mile north of Choukpazat village, and consists of a ten head stamps battery (750lbs. stamps, 7 inch drop, 92 blows per minute, ·02 inch screens) with ordinary amalgamated copper plates and two small shaking tables: nine dwts. of gold per ton are obtained by amalgamation. Concentrates are collected on two Frue Vanners and are being stored with a view to the erection of a suitable plant for their treatment. The tailings contain 3 dwts. of gold per ton: a small cyanide plant is being erected to deal with them. The following table illustrates the method:—

ORE.

Free gold.	Concentrates.	Tailings.
Amalgamated in the boxes of the battery and on the copper plates.	Sorted and awaiting treatment.	To be treated by a small cyanide plant in course of erection.

There is no doubt that free gold will be found in the auriferous shoots at greater depths than 420 feet to which the Choukpazat vein has been proved. This feature is of importance because it means that a fair percentage of the gold in most of the workable lodes can be extracted by the aid of simple machinery. Only one complete plant is necessary for the district, and the concentrates from the smaller mines could be sold on assay value to the owners of the larger plant. There has not been as favorable an opportunity as the present for the development of small mines: a comparatively

G. F. Reader.


Sit
K
U N C
Ulab Stream
K
R
Chaurimel Nala
681
Stream
R
672
Khaliabahal Road
Sitaram Strea
Bonjari
B O N J A R
R
656
Piplimal
Nala
Kodalo
Nala
Ghenor
REFERENCE
Gneiss
Talchirs
Kamthis
Barakars
Assumed Outcrops
Supposed Fault
K K K K K: boreholes put down by B. N. Railway
R R R R R R R: holes put down this Field-Season.
Approximate heights above Sea-level are shewn by large figures.

small addition would make the Choukpazat plant suitable for the purpose indicated.

Legyin.

Eleven miles north of Choukpazat an area is being prospected by Mr. N. Lazarus. Several quartz veins have been discovered and a level thirty-four feet in length has been driven along a reef bearing north-west and heading 10 degrees to the south-west. The reef varies from 15 inches to 2 feet in width, is well defined and worthy of exploitation. The other veins, referred to, have not been prospected.

Conclusions.

The two properties described in this report are the only places where work is in progress, and as will be seen from my remarks only one payable vein has been found up to date.[1]

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Preliminary Report *on the* Rampur Coal-field, *by* G. F. READER, F.G.S., *Mining Specialist, Geological Survey of India.*

Area examined.

The part of the Rampur coal-field which has been examined this field-season (December 10th 1899 to February 17th 1900) is shown on the map (dated 1875) as lying between parallels 21° 45′ and 21° 51′ and meridians 83° 50′ and 84° 1′.

The previous writers on this coal-field are :—

Previous Writers.

Dr. V. Ball, Rec., Geol. Surv. of India, Vol. viii, pt. 4; Dr. W. King, Rec., Geol. Surv. of India, Vol. xvii, pt. 3, Vol. xviii, pt. 4, Vol. xix, pt. 4, Vol. xx, pt. 4.

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[1] Since the above was written, Mr. Stonier has discovered a quartz reef with payable gold about 14 miles north of Baumank. The reef consists of quartz, is nine inches in thickness and where tested it contains 9 dwts. of gold per ton of ore. There is also about 2 per cent. of copper in the form of chalcopyrites.

Previous History.

One thick band of carbonaceous shale with coal-bands interbedded and several minor seams were disclosed in the Lillari stream. As the result of surface exploration in this area, and evidence deduced from bore-holes put down in the Lillari valley under his directions in 1884 to 1886, Dr. King says, "I am reluctantly compelled to recommend its abandonment." In a later Report (Vol. XX) Dr. King, not considering the evidence of bore-hole samples sufficiently trustworthy, advised sinking a pit near Chowdibahal. The general results of these investigations were, however, considered unfavourable, and no further action was taken in prospecting for coal until the discovery of a seam of coal under the site of the Eeb bridge on the Bengal-Nagpur Railway. On this discovery a grant was made by Government to the Bengal-Nagpur Railway Company to explore the coal area round Telanpali. For this purpose five bore-holes and one shaft were put down. I have marked four bore-holes and the shaft on the annexed sketch-plan of the area. One bore-hole I have not been able to locate on account of the inaccuracy of the map. The general result of this exploration (by the Bengal-Nagpur Railway Company) was not encouraging, but on the report being submitted to Mr. Griesbach, he advised the deepening of bore-hole No. 4 (K4 of map) until undoubted Talchir rocks were struck "not being satisfied that the lower measures of the Barakars (which usually contain the best coal seams)" had been sufficiently proved. In pursuance of this opinion Government sanctioned the work of carrying the boring to a depth of 400 feet and subsequently to a depth of 600 feet. At a depth of 347 feet a seam of coal 7′ 9″ thick, with a 6″ band of stony coal in the middle, was struck, then for a hundred feet a remarkable succession of alternating bands of thin coals and shales were encountered, and the remaining 37 feet passed through "fine-sandstone"—the hole being stopped at a depth of 485 feet in this sandstone before reaching the Talchirs.

This boring result was deemed by Mr. Griesbach sufficiently encouraging to advise going on with the work for another 100 feet or so, unless the crystalline rocks were struck at a lesser depth. The boring contractors pointed out that the cost of drilling to this depth would be very great, and Mr. Smith was deputed to visit the spot to ascertain whether it could be regarded as reasonably certain that two borings to a depth of 500 feet would give the same information as one to a depth of 1,000 feet and if strong evidence existed in favour of this conclusion, to mark the exact position at which the second bore-hole should be drilled with reference to the one under discussion.

The examination did not answer this question and it was considered a better plan to select a site near Dhoramuda, practically at the top of the Barakars, and bore through the whole thickness to the Talchirs or Crystallines as the case might be. Had the coalfield been previously laid down on an accurate map I venture to think that such site would not have been chosen, since it would have been evident that at that point the thickness of measures would be nearly if not quite double what they were anticipated to be. However a bore-hole was put down here to a depth of 828½ feet only which passed through several shaly coal seams (not one workable) finally stopping in the zone of Barakar Rocks exposed in the Lillari nala near Piplimal, several hundred feet above the top (geologically speaking) of the Kodopali boring (No. 4) and only proved the ground already proved by Dr. King in his Nos. 1, 2a, 3, 4, 5 and 6 bore-holes. It will therefore be seen that the lower measures of the Barakars have not been proved as was intended.

Object of present survey.

Inaccurate map.

The object of this survey was to reconcile as far as possible previous apparently conflicting data and ascertain the probability of existence of a workable seam or seams of coal. My first endeavour was to establish a working vertical section from exposures in the Lillari valley for correlation with parallel sections in the Eeb river and Bichwa nala, and to enable me to fix the horizons of the seams discovered in the various bore-holes in the course of this preliminary work, I was forced to the conclusion that the topographical sheet was not sufficiently accurate for recording geological observations. I was therefore compelled to re-survey the whole area topographically and as a consequence geologically too.

Scope of report.

For the purpose of this Progress Report I will confine myself to the economic resources of the field, leaving the data upon which the geological map is based for my final report.

Estimate of thickness.

Work was commenced in the Lillari nala and as complete a working section as possible was established from surface observations, from the Talchirs up to the Kamthis. On the evidence of this section alone I should place the thickness of the Barakars at about two thousand feet. There is a great difference between this figure and those of previous writers. The inaccurate map previously used will account for some of it, but even then I fail to understand why so low a figure was assumed. I have not, however, been able as yet to make use of the evidence deducible from Dr. King's bore-holes in the Lillari valley, since no information is to hand of their exact positions.

Seams in the Lillari nala.

Four carbonaceous bands were met with in the Lillari nala (see plan R^1, R^2, R^3, R^4) near Durlipali, Bonjari, Khaliabahal, and Dhoramuda Ghât. Small pits were sunk into these outcrops and the following sections obtained:—

DURLIPALI :—*Base of seam* R^1.

	Ft.	in.
Two inches of coal with shale	0	11
Argillaceous shale	3	0
Carbonaceous shale	2	0
Coal	0	2
Carbonaceous shale		
Base		

Bonjari, R^2.

	Ft.	in.
Argillaceous shale	2	0
Clay ironstone	0	3
Carbonaceous shale	2	3
Coal	0	9
Carbonaceous shale	1	0
Coal	0	5
Carbonaceous shale	0	9
Coal	0	5
Carbonaceous shale	1	4
Coal	0	2
Carbonaceous shale	0	7
Coarse sandstone		
Base		

Khaliabahal, R^3.

Top	Ft.	in.
Clay	2	0
Carbonaceous shale	0	4
Coal	0	4
Carbonaceous shale	0	4
Shale with coal-pipes	2	4
Carbonaceous shale	1	0
Coal	0	6
Carbonaceous shale	0	5
Coal	0	2
Carbonaceous shale	0	10
Sandstone		
Base		

Dhoramuda Ghât, R^4.

Carbonaceous micaceous shale	2	6
Sandstone		
Base		

It will be seen that none of these bands contains coal of workable thickness. Nevertheless samples of coal were extracted from each band and tested. The result was indifferent in each case, the average ash exceeding 35 per cent.

On the result of these holes, however, I do not feel justified in condemning these seams. It is highly probable that some change will be found to take place in their quality to the east and west and to the dip of the point proved.

My next intention was therefore to get a correlative section in the Bichwa nala—marked on the Topographical Survey map as flowing more or less parallel to the Lillari nala, and about a mile or a mile and a half to the west of it—to see how these seams varied in quality and thickness, etc., to the west and to get some idea as to the nature of the ground intervening. I was very much disappointed on finding that there is no Bichwa nala, nor any other stream flowing towards the south; indeed the water from the hills ranging from Burtab to Sahujbuhal flows to the east into the Lillari.

New plan and deductions.

By this time, however, my new plan was beginning to show the topographical map more incorrect than I had thought, and it became evident that opinions based on work done on this map must require reconsideration; in fact, the correlation of the Eeb Bridge and Durlipali seams did not appear plausible.

Modlia nala.

I then turned my attention to the neighbourhood of the Eeb river and the nalas flowing into it on the right bank and the Bonum nala on the left bank. Commencing near the source of the Modlia nala diligent search was made for some shale or coal seams to correlate with the Bongasi and Khaliabahal beds. In its upper reaches the Modlia nala gives many rock sections, and I was therefore at a loss to understand why some carbonaceous shale or coal beds were not met with. The discovery of what appear to be Talchir shales, however, further down the stream proving, in such a case, a down throw fault to the east, explained this and at the same time showed that representatives of these carbonaceous shale beds must be sought for much further to the west and north than this report is dealing with.

Eeb river.

Attention was then directed to the Eeb river, and here I was successful in unearthing, as anticipated, coal outcrops (correlating with the Eeb Bridge seam) at two points—R^7, R^6—of great moment in that they will materially aid in solving the field—approximately 1¾ and 3 miles down the river from the bridge.

Holes were put down at these points and also at Lumchibahal Bridge (R ^{5}), where curiously enough, the same seam, I believe, was proved on the same day—I thought then for the first time, but subsequently found it was not so.

The sections, as deep as the pits could be taken with the labour at hand, are—

	Rampur section R^{6}.	Ram Adin section R^{7}.	Lumchibahal R^{5}.
	Ft. in.	Ft. in.	Ft. in.
Conglomerate	...	...	...
Grey shale.	...	...	7 0
Black earth	4 0	6 0	5 6
Coal	4 9	2 2	1 6
Batt	0 8	1 6	
Coal	3 1	3 3	
Batt	1 9		
Coal anticipated	↓	↓	↓

Laboratory and also large scale tests were made with the following average result: (Moisture $9^{\circ}/_{0}$, vol. m. $17^{\circ}/_{0}$, ash (red and white) $15^{\circ}/_{0}$ variable, and fixed carbon upwards of $51^{\circ}/_{0}$. Seven maunds of coal taken from the lower parts of the Rampur seam gave $12\frac{1}{2}^{\circ}/_{0}$ of reddish ash—one little bit formed a clinker. Generally, the coal may be said to be of fair quality, parts very good, ignites freely, and, except that one bit clinkers, open-burning, suitable for steam purposes and of workable thickness.

It may, I think, be safely assumed that this is the Eeb seam. Such being the case the outcrop of this seam is seen to be duplicated, and this point itself is almost sufficient to prove the existence of a down throw fault (and to a certain extent locate it) to the east, since the seam dips to the west. In addition to this evidence, however, the occurrence of Talchir shales in the Modlia nala, the positions of the basement white Barakar sandstones on both sides of the Eeb Bridge and at Telanpali, the absence of coal in the No. 1 bore-hole of the Bengal-Nagpur Railway Company (K^1 on map) and the presence of a spring near Rampur are sufficient to warrant the assumption, and determine the line of a down throw fault to the east as shown on the plan.

Horizon of the Eeb Bridge seam.

Upon what grounds the Eeb coal seam has been identified with the Durlipali shale bed I do not know, but I am certainly not of that opinion and indeed think that the Eeb seam is the lower by some 200 to 300 feet. If the exact position of the bore-holes put down by Dr. King in the Lillari valley and also that of the Bengal-Nagpur Railway Company, 'No. 3' can be ascertained, this point could, I think, be settled beyond doubt.

Conclusion.

In conclusion I would like to add that further action in this area should be directed towards the immediate exploitation of the Eeb coal seam and the completion of bore-hole No. 4 (K^4 of map) down to the Talchirs. At the same time the Bonjari and Khaliabahal beds might be followed up to the west and north, for, as I have before stated, it is not improbable that these beds will improve; and here it is necessary to add that such further exploration cannot be carried out in a satisfactory manner unless accurate topographical maps be supplied upon which data already known can be mapped and deductions drawn therefrom.

Preliminary Report *on the* Sohagpur Coal-field, *by* G. F. READER, F.G.S., *Coal Specialist, Geological Survey of India.*

In Volume XXI, Part 3, of the Memoirs of the Geological Survey of India, Mr. Hughes describes the above coal-field, and records the existence of the coal seams which came under his notice, and at the same time he makes such observations on each seam as his preliminary investigation would allow. The present survey is intended to collect more practical details of some of the most promising seams mentioned by Mr. Hughes, and of other seams encountered during its progress.

Object of Survey.

On page 46 of the Memoir referred to, Mr. Hughes states :—

"The main seam comes to the surface between Bargaon and Kelhauri, once in the Jamunia, thrice in the Sōn, frequently in the Bagéha, and twice in the Nargàra seams. It covers a large and easily workable area or either side of the Sōn, and it can be picked up along its strike for a distance of 10 miles. It is the seam '*par excellence*' of this part of the field."

Amlei seam.

On such a prescript I pitched my camp at Burharand and commenced operations in the neighbourhood of this seam. In amplification of the above abstract, I am now in a position to say that a good seam of workable coal crops out near Amlei in the Bagéha nala and also about a mile further south-west in the same nala. It dips about 3° to the north-west, and to judge from its strike, I am at present inclined to think that it may be correlated with a seam exposed in the Sōn 7 miles north-east of the Amlei exposure and 1½ miles north-east of Bokahi. The section of the seam is :—

AT AMLEI.

	Ft.	in.
Massive sandstone . .		
Banded " . .	1	6
Fireclay shale . .	2	6
Soft coal . . .	1	5
Carbonaceous shale .	0	5
Hard coal . . .	0	6
Soft " . . .	2	1
Hard " . . .	7	0
Shaly " . . .	1	2
Soft " . . .	2	8
Carbonaceous shale .	0	2
Sandstone		
Base		

IN THE SŌN.

	Ft.	in.
Massive sandstone .		
Gritty sandstone . .	4	0
Hard coal . . .	4	8
Gritty sandstone . .	2	0

If these seams be correlated it will be seen that a thickness of 15 feet 5 inches of carbonaceous matter at Amlei (containing 13 feet

8 inches of good coal) is represented by 4 feet 8 inches of coal in the Sōn. In such case, whether the decrease in thickness is due to splitting up or actual thinning out, remains to be proved. I favour the former supposition, and indeed think that a further search in the Sōn will reveal the upper part of the Amlei seam. The analyses made by Sub-Assistant Hira Lal gave the following results:—

	AMLEI BAGÉHA.	BOKAHI SŌN.
Moisture	5·2 per cent.	Nominal.
Volatile matter . . .	22·2	27·4
Fixed carbon	57·2	61·0
Ash	15·4	11·6

The calorimeter and large scale tests confirm these results—the evaporative power of the former exceeding 12·5 and the latter 12·9 when conducted on general samples (not dried). It is a free burning, non-clinkering, hard coal, and suitable for steam purposes.

The next most productive coal-bearing band strikes from south of Sabo in the Bagéha nala up the stream to north-east of Dhanpuri in the Nargara nala. Several pits were sunk along this strike and the following sections obtained:—

NORTH-EAST OF DHANPURI NAGARA NALA.

	Ft.	in.
Carbonaceous shale .	0	4
Coal	0	4
Carbonaceous shale . .	0	4
„ clayey shale	0	6
Coal	2	9
Carbonaceous shale . .	0	6
Coal	1	0
Hard sandstone . .	1	7
Soft „ . .	0	5
Hard „ . .	2	0
Carbonaceous shale . .	1	2
Coal	1	10
Carbonaceous shale . .	0	9
Coal	2	3
Carbonaceous shale . .	0	7
Sandstone . .	1	6

WEST-NORTH-WEST OF JHAGRAHA BAGÉHA NALA.

	Ft.	in.
Coal	3	8
Carbonaceous shale .	0	8
Coal	0	9
Carbonaceous shale .	0	4
Coal	2	9
White sandstone . .	5	2

SOUTH OF SABO IN TRIBUTARY OF BAGSHA NALA.

	Ft.	in.
Black dirt	4	0
Hard *coal*	4	3
Carbonaceous shale	0	4
Coal	0	6
White sandstone	0	4½
Shale	0	1
White sandstone	0	4½
Carbonaceous shale	0	6
White sandstone	3	0

SOUTH OF SABO IN BAGSHA NALA.

Ft.	in.	
2'	0"	Sandstone.
2'	0"	Micaceous sandstone.
3	5	Carbonaceous shale.
1	3	*Coal.*
2	2	Carbonaceous shale.
0	9	*Hard coal.*
0	5½	Carbonaceous shale.
3	0	*Coal.*
1	10	Carbonaceous shale.
1	5	*Hard coal.*
2	6	*Coal.*
2	0	White sandstone.

Whether the above sections (Dhanpuri, Jhagraha, and Sabo) represent two or three seams, I am not yet in a position to state. Reasoning from the dip and strike of the measures the Dhanpuri section is the outcrop of one seam and the Jhagraha and Sabo sections the outcrop of another seam. Taking the sections and qualities only into consideration, however, there appear to be three seams, *i.e.*, Dhanpuri, Jhagraha, and Sabo sections; each represents a different outcrop and as such I prefer to treat of them.

Dhanpuri seam.

The Dhanpuri seam presents a most tantalizing section to a practical man: two bands of coal, each only just thick enough to be comfortably workable with a band of shale in the middle, and a clay shale roof. The question how to work this seam might well be asked by an examining Board in England—if the Board itself could agree as to what the answer should be. If, however, its section is half and half, so to speak, its quality is a little better. The average analysis of a general sample is:—

Moisture	7 per cent.	Evaporative power *approximately 12.*
Volatile matter	25 „ „	
Fixed carbon	53 „ „	
Ash: (clinkers)	15 „ „	

Jhagraha seam.

The Jhagraha seam certainly presents at its outcrop a fair workable section and the coal looks good. To my surprise, however, large and small scale tests gave very bad results: average ash percentage is 42, calorific power 5153 calories or 9·9 evaporative power.

Sabo seam.

The Sabo seam presents a better section than the Jhagraha and as regards quality also it is a good seam. Its analysis gives :—

Moisture	1 per cent.	Evaporative power 12·7 per cent.
Volatile matter . .	21·4 „	
Fixed carbon . . .	60·8 „	
Ash (little clinker) . .	16·8 „	
	100	

In addition to the above at least three other seams deserve mention. One, half a mile east of Bargaon 3 feet 8 inches thick; one, in the Bakan nala, 600 yards from its junction with the Sōn, 4 feet 4 inches thick; and one, near Rampur, in a tributary of the Katna river, 5 feet 6 inches thick, with a band of shale in the middle.

Other seams.

Tests have not as yet been made on these. Their thicknesses are workable and preliminary experiments point to a fair quality.

Summary.—In descending order the seams appear to come as follows :—

Sabo (in Bagéha nala).
Jhagraha (Ditto).
Dhanpuri (Nargàra nala).
Amlei-Bokahi (Bagéha and Sōn).
Bargaon-Kelhauri.
Rampur (tributary of Katna).
Bakan (Bakan nala near Sōn).

Of these the Sabo and Amlei-Bokahi have given workable thicknesses and very fair qualities. The Jhagraha and Dhanpuri seams have not given satisfactory results, but may be found on further exploitation to improve in quality and section respectively. The Bargaon-Kelhauri, Rampur and Bakan nala seams give workable thicknesses and preliminary experiments point to fair qualities.

Preliminary Report *on the* Geology *of the* Northern Shan States, *by* TOM D. LATOUCHE, B.A., *Superintendent, Geological Survey of India.*

CONTENTS.

PAGE.
I. INTRODUCTORY 74
II. LIST OF FORMATIONS AND FOSSIL LOCALITIES 75
III. DESCRIPTION OF FORMATIONS 81
1. Sedaw limestone 81
2. Red crinoid beds 82
3. Nyaungbaw beds 82
4. Naungkangyi beds 83
5. Zebingyi beds, Trilobite beds 83
6. Ditto, Graptolite beds 83
7. Maymyo beds 84
8. Kyinsi beds 84
9. Namyao beds 85
10. Tertiary beds 85
11. Recent formations 86
IV. STRATIGRAPHICAL DETAILS ALONG THE ROUTE TAKEN 87

I.—INTRODUCTORY.

The tract of the country described in the present report is that portion of the northern Shan States which lies along the line of railway now under construction between Mandalay and the Kunlon ferry on the Salween; that is, between the 22nd and 23rd parallels of north latitude and extending from about the 96th to a little beyond the 98th degree of east longitude. This route had been traversed before by Dr. Fritz Noetling, who in 1890 visited and reported on the coal-fields of Lashio and the Nam Ma valley in the eastern portion of the area.[1] Dr. Noetling proved the presence of lower silurian rocks near the western edge of the hills, between the 22nd and 26th miles on the cart-road, then being constructed from Mandalay to Lashio, and described some of the fossils he obtained from them in a short paper in the *Records.*[1] The most important was a gigantic form of the cystidean *Echinosphærites*, to which he gave the name of E. Kingi. I had a great advantage over Dr. Noetling in being able to avail myself of the numerous cuttings along the railway, which for the greater part of the distance runs close to the cart-road. Moreover, I was not hampered with considerations of economic geology, but was able to devote myself entirely to the working out of the stratigraphy along the routes. Consequently I was able to add considerably to the number of localities in which fossils are obtainable, and to prove the existence of a series of palæozoic formations in addition to the lower silurians discovered by Dr. Noetling. When I left the line of the railway, however, and attempted to penetrate into the country on either side, I experienced the same difficulty as Dr. Noetling, in finding outcrops of solid rock. The enormous thickness of clay, derived from the weathering of the prevailing limestones, with which the rocks are covered, is well seen in many of the railway cuttings. Cliff sections are rare, and the rocks forming them are often concealed by masses of stalactites, while the rocks in the beds of the streams are nearly always concealed by a coating of calcareous tufa, deposited by the lime-laden waters, and often several feet in thickness.

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[1] Records, G. S. I., Vol. XXIV, Part 2, p. 99.

The physical features of the hills have already been described by Dr. Noetling in the report published in Vol. XXIV of the Records, Geological Survey, above referred to.[2] Since I followed the same routes I have nothing to add to his description. Further detailed examination of the country to the north and south of the railway, with the help of more accurate maps, and on a larger scale than those now obtainable, is required before the orography of the district can be fully discussed.

II.—LIST OF FORMATIONS AND FOSSIL LOCALITIES.

The formations met with along the railway and cart-road between the foot of the hills at Sedaw and the Salween at Hsopket, east of Lashio, are the following, in descending order:—

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[1] Records, G. S. I., Vol. XXIII, Part 2, p. 78.

[2] p. 101.

No.	Period.	Description of beds.	Local Name.	No.	Localities.	Latitude, approx.	Longitude, approx.
						° ′ ″	° ′ ″
11	Recent . .	Valley gravels and alluvial deposits with numerous land and fresh-water shells.	...	...	Nam Tu (Myituge) valley near Hsi Paw, and generally in the larger river valleys.	...	...
		Older gravels and boulder beds.	...	...	Lower slopes of hills in the neighbourhood of Hsi Paw.	...	...
		Red or yellow clays, often of great depth, and sometimes consolidated by the infiltration of carbonate of lime into a hard-rock, containing land and fresh-water shells.	...	...	Railway cuttings near Naurighkio.	22 20 0	96 51 0
					3 miles east of Lwekaw	22 33 0	97 11 0
		Similar clays hardened by infiltration of iron oxide, laterite, occasionally sufficiently rich to be worked as an iron ore.	...	...	Near Waboye village	21 58 0	96 25 0
10	Tertiary . .	White and yellowish sandstones with grey and brown clays and coal seams.	...	...	Lashio. Nam Ma Valley.	...	...

9		Red and brown sandstones with numerous bands of red clay and coal shales.	Namyao beds .	1	Mandalay-Kunlon Railway, about a mile above junction of Namyao and Nam Ma near Se Ing.	22 43 0	97 34 0
8	Devonian .	Grey and olive shales with concretionary masses of dark blue limestone.	Kyinsi beds .	2	Mandalay-Kunlon Railway, west end of deep cutting at Kyaukkyan, about 6 miles west of Naunghkio.	22 18 0	96 46 0
				3	Mandalay-Kunlon Railway about a mile west of Kyinsi village, near junction of Namsim and Nam Tu.	22 33 0	97 14 0
					Mandalay-Kunlon Railway between Waboye village and Maymyo.	...	...
7	(?) Upper silurian	Thick beds of limestone, generally siliceous, or calcareous sandstones, white or grey, with subordinate bands of argillaceous shale or "Fuller's earth."	Maymyo beds .	4	Mandalay-Kunlon Railway, spoil pits about 5 miles north-east of Maymyo.	22 4 0	96 34 0
				5	Mandalay-Lashio cart-road, mile 55, close to village of Wetwun (Wenwi).	22 6 0	96 39 0

No.	Period.	Description of beds.	Local Name.	No.	Localities.	Latitude, approx.	Longitude, approx.
						° ′ ″	° ′ ″
7	(?) Upper silurian	Thick beds of limestone, generally siliceous, or calcareous sandstones, white or grey, with subordinate bands of argillaceous shale or "Fuller's earth."—*contd.*	Maymyo beds	6	Mandalay-Kunlon Railway, spoil pits 2 miles north of Gokteik station.	22 22 30	96 58 0
				7	Mandalay-Kunlon Railway, about 3 miles west of Lwekaw.	22 33 0	97 6 0
				8	Mandalay-Lashio cart-road, mile 169.	22 44 0	97 42 30
				9	Bridge on Lashio-Kunlon road, about 4 miles north of Lashio.	22 59 30	97 49 30
				10	Isolated hill, about a mile west of Mongyaw	23 1 30	98 7 0
				11	Mandalay-Kunlon Railway, 2nd cutting, below mile 21. Scarp below Zebingyi village.	21 54 0	96 20 30

6	Upper silurian .	Black calcareous shales with bands of hard black, or dark grey limestône.	Zebingyi beds.	Graptolite beds.	12	Mandalay-Kunlon Railway, cutting about a mile east of Zebingyi station.	21 54 0	96 22 0
					13	Bed of stream about half a mile north of Pyinsa village, Mandalay-Lashio cart-road, mile 28.	21 52 0	96 24 30
					14	Mandalay-Lashio cart-road, mile 32, about a mile north of Thondaung rest-house	21 54 0	96 24 30
					15	Mandalay-Kunlon Railway about half a mile east of Thondaung (Waboye) station.	21 56 30	96 25 30
5		Soft, yellow, sandy shales and sandstones with nodular beds of limestone.		Trilobite beds.	12	See above.		
					14	See above.		
					16	Mandalay-Lashio cart-road, crest of ridges west of Pyinsa village.	21 52 0	96 23 30
					17	Mandalay-Lashio cart-road, mile 88½, east side of Gokteik gorge, above Chaungyou rest-house.	22 22 0	96 53 30
					18	Mandalay-Kunlon Railway, cutting about 5 miles east of Pyaungaung.	22 31 0	97 3 30

No.	Period.	Description of beds.	Local Name.	No.	Localities.	Latitude, approx.	Longitude, approx.
						° ′ ″	° ′ ″
4	Lower silurian	Grey and olive green shales and limestones, weathering into soft sandy shales.	Naungkangyi beds (? Bala or Caradoc).	19	Hills 2 miles north of Maymyo on path to Naungkangyi.	22 3 0	96 30 30
				20	Left bank of river north of Nawughkio,on path to Nahung village.	22 21 30	96 50 0
				21	Mandalay-Lashio cart-road zigzags between miles 84 and 86, Gokteik gorge.	22 21 0	96 52 30
3		Flaggy limestones separated by bands of shale and clay, occasionally carbonaceous.	Nyaungbaw beds.	22	Mandalay-Kunlon Railway, mile 19, below Zebingyi.	21 53 30	96 19 30
				...	Mandalay-Lashio cart-road, mile 22 near Nyaungbaw rest-house	21 51 0	96 20 0
2		Dark red calcareous shales.	Red crinoid beds (Pyintha beds, Noetling).	23	Mandalay-Kunlon Railway, between 3rd and 4th reversing stations above Sedaw.	21 53 0	96 18 0
				24	Mandalay-Lashio cart-road, miles 25 to 26 on ascent from Nyaungbaw toPyinsa.	21 51 0	96 23 0
1		Massive and flaggy limestone traversed by numerous veins of calcite.	Sedaw limestone (Mandalay limestone, Noetling).	...	Zigzags on railway above Sedaw.		

It is very seldom, indeed, that the actual contact between any two of these formations can be seen. Everyone of the beds, from the red sandstones downwards, has been greatly crushed, folded, and faulted and the dips often vary considerably both in direction and amount within the space of a few yards. Thus it is impossible to say whether the beds mentioned above form a continuous conformable sequence or not. There are some indications of an overlap of the upper silurian limestones (No. 7) on the underlying formations, though there is no direct evidence of an unconformability. Thus the black graptolite shales of Zebingyi (No. 6) were not found anywhere to the east of Maymyo, though the trilobite beds (No. 5) which underlie them in the Zebingyi sections are found immediately beneath the white limestones in the Gokteik gorge, and again still further to the east near Pyaunggaung. It is quite possible, however, that the graptolite beds were originally merely a local deposit.

Generally speaking, there is a distinct zonal arrangement of the different formations, the oldest occurring along the western edge of the hills, while as we proceed eastwards newer formations are successively crossed. The general strike is between N.-N.-E. and E.-N.-E., but it varies greatly within short distances. This is also the general direction of the railway and cart-road, so that they often run for several miles on one and the same formation.

III.—DESCRIPTION OF FORMATIONS.

1.—*Sedaw limestones.*

This is the " Mandalay limestone " of Noetling, but I am not at all sure that the limestone which forms the Mandalay hill and other isolated hills in the Irrawaddy valley, between Mandalay and the edge of the Shan plateau, is the same as that found on the steep ascent from Sedaw. It is possible that the limestone in the plain belongs to a much higher position in the series, but in the absence of recognizable fossils it is impossible to be sure of this. The Sedaw beds consist of hard dark blue or grey limestones in thick beds, traversed by numerous veins of white calcite, greatly crushed and folded. In the railway cuttings on the zigzags above

Sedaw, sections of *bivalves, gastropods*, and *crinoid* stems are common on the weathered surface of some of the beds, but cannot be extracted in a sufficiently well preserved condition for identification.

2.—*Red crinoid beds.*

These consist of dark red calcareous shales greatly crushed, and traversed by numerous gliding planes, slicken-sided surfaces being very common, with veins of calcite running through them in all directions. Everywhere they contain scattered joints of small crinoid stems, usually not more than ⅛ or ¼ inch in diameter, but rendered conspicuous by the contrast of the white calcite of which they are composed, with the dark red colour of the rock. Hand specimens showing these crinoid stems resemble very closely the red crinoid shales at the base of the carboniferous series in the Central Himalayas,[1] but the latter are undoubtedly newer than upper silurian, while these are lower silurian. It is in these beds (called by Dr. Noetling the Pyinsa group), that *Echinosphærites Kingi*, described by him in Vol. XXIII, Part 2, of the *Records*, is found, but it appears to be very local in its occurrence; and although very good sections of the red crinoid beds are exposed in the railway cuttings above Sedaw, I did not come across a single specimen of it. Fragments of *Orthoceras* are also found in these beds and are locally numerous.

3.—*Nyaungbaw beds.*

The red crinoid beds pass upwards into a considerable thickness of flaggy limestones in regular layers, separated by bands of clay or shale. Occasionally the latter are somewhat carbonaceous. Fossils are fairly numerous in places, and consist mostly of *Orthoceras* and other cephalopods, generally in fragments, *crinoid* stems, and fucoid impressions. Near the village of Nyaungbaw, at mile 22 on the Lashio cart-road, Mr. Datta found some fairly well-preserved specimens of *crinoids* showing portions of the calyx and arms as well as fragments of the stem. These are associated with *Orthoceras* and appear to be quite local in occurrence. I could not find them in the cuttings along the railway, where these beds are very well exposed, but at the nineteenth mile *Orthoceras* occurs in considerable numbers.

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[1] Griesbach, Mem. G. S. I., Vol. XXIII, p. 61.

4.—*Naungkangyi beds.*

In the railway cuttings below Zebingyi the beds just described are followed immediately by a bed containing upper silurian fossils, but in the Gokteik gorge, a long way to the east, another outcrop of lower silurian beds is found, which is not represented to the west of Maymyo, though it occurs in the hills a couple of miles to the north of that place. The beds consist of a considerable thickness of grey calcareous sandy shales, with bands of limestone, sometimes weathering into soft, reddish yellow, sandy shales. They contain great numbers of casts of *Orthis*, *Strophomenas*, etc., with single plates of cystideans, some of which resemble very closely *Mimocystites bohemicus* (Barr.), from the stage D^{2} (=Bala or Caradoc) of Bohemia.[1] The manner in which the casts of *Orthis* are matted together on the surface of the slabs, and the general appearance of the rock, reminds one very strongly of the Caradoc beds of Shropshire.

ZEBINGYI BEDS.

5.—*Trilobite beds.*

In the neighbourhood of Zebingyi the flaggy limestones of the Nyaungbaw series are followed by soft, yellow, sandy beds with nodular bands of limestone, containing large numbers of *Orthoceras* and fragments of *Trilobites*, with a few small *lamellibranchs* and *brachiopods*. The *Trilobites* are not very common and are generally badly preserved. In the Gokteik gorge similar beds occur containing heads of *Eucrinurus punctatus*, east of *Orthis* and *Petraia*.

6.—*Graptolite beds.*

These consist of black calcareous shales with bands of hard dark grey or black limestone containing large numbers of *Graptolites*, all of the monoprionidian order, though they are frequently so crowded together on the surface of the rock, that it is difficult to make out whether double forms occur or not. A small

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[1] Barrande, Syst. Silur. de Boheme, Vol. VII, pl. 28.

Tentaculites closely resembling *T. elegans*, Barr.,[1] is very common and is a most useful fossil in tracing out the distribution of these beds, for it appears to be almost entirely confined to this horizon and is not easily destroyed by weathering, so that it can be recognized even in outcrops where the rock has been reduced to a soft clay.

The graptolite beds are only a few feet in thickness and occur only in this section west of Maymyo.

7.—*Maymyo beds.*

The graptolite beds are followed by massive white limestones, always characterized by the presence of a considerable amount of siliceous material; in fact, the rock is sometimes rather a calcareous sandstone than a limestone. These rocks may be traced almost continuously from near Thendaung (Waboye) station about eight miles west of Maymyo to the Salween,—a distance of nearly 200 miles. They are not very fossiliferous, but casts of small *gastropods* and a *lamellibranch*, probably a *Pterinea*, are numerous in some places, and help considerably in identifying these rocks in the small outcrops, which are often all that can be seen of them protruding through the thick covering of red clay. In a few places beds of argillaceous shales resembling Fuller's earth are found among these limestones, but I could never find them in actual contact; so that I could not discover whether the shales occur at any particular horizon in the limestones, or not. These shales contain a fairly rich fauna including a small *Lingula*, many *bivales*, and a fossil that looks like a *Theca* or *Hyolithes*, but none of them appear to be very characteristic. They may be either uppermost silurian or perhaps devonian.

The thickness of the limestones must be very great. They form the great precipices seen on either side of the Gokteik gorge and many lofty scarps in the neighbourhood of Lashio, but they are so much cut up by faults that it is impossible to form any estimate of their true thickness.

8.—*Kyinsi beds.*

The white limestones are succeeded by a band of shales of no great thickness with concretionary masses of hard blue limestone.

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[1] Barrande, op. cit., Vol. III., pl. 14.

Both shales and limestone are highly fossiliferous, but in the latter the fossils only appear as sections on the weathered surface of the rock and complete specimens cannot be extracted. In the shales, on the other hand, the fossils can be easily extracted and are of great variety. Among *lamellibranchs* a *Pecten* is very common, and a small *Conocardium* occurs. A small *gastropod*, probably *Murchisonia*, also occurs in large numbers. The fossils collected have not yet been specifically determined, but it seems probable that the beds are devonian. They contain no typically silurian or carboniferous fossils, so far as I have been able to judge from a cursory examination, nor can any of them be referred with certainty to the mesozoic period, though I thought, when I first discovered them, that the beds might possibly be jurassic. The presence of *Conocardium* seems to point to their being upper palæozoic.

9.—*Namyao beds.*

The shales just described are followed by a great thickness of red beds, consisting of rapidly alternating layers of sandstone and shales or clays. These beds were described by Dr. Noetling as "red sandstones of undetermined age." They apparently rest conformably upon the grey fossiliferous shales near Kyinsi, but to the east of this the latter appears to be absent, and the red beds rest upon the white limestones (No. 7). Excellent sections of them are seen in the railway cuttings along the Namyao valley, between Hsi Paw (Thibaw) and Lashio, but fossils appear to be very rare. I obtained a few from one locality near the junction of the Namyao with the Nam Ma, but all are in a very fragmentary state, and none of them, I am afraid, can be specifically determined. They resemble, however, to some extent, the fossils from the grey shales below, and it seems probable that these and the red beds belong to one series. If this is the case, the whole of the mesozoic period is quite unrepresented in the portion of the hills traversed by the Mandalay-Kunlon Railway, for the only rocks that occur on this route, higher than the red sandstones, are of tertiary age. Some of these red sandstones form an excellent building stone.

10.—*Tertiary formations.*

The tertiary system in the northern Shan States, with the accompanying coal seams, has been described in detail by Dr. Noetling.[1] The route which I followed did not cross these beds anywhere. They seem to be entirely confined to the river valleys and to be of very small extent. No doubt when the railway is opened to Lashio the coal will be made use of to some extent, though it is doubtful whether it will be worth exploiting on a large scale.

11.—*Recent formations.*

The chief superficial feature of the plateau, from a geological point of view, is the thick mass of clay, generally bright red in colour with which, practically, the whole of the country is covered. It has mainly been derived, in all probability, from the weathering of the limestones, principally the white and grey, sandy limestone of the upper palæozoic era, which is the prevailing rock. In the railway cuttings this deposit is often seen to reach a thickness of 40 or 50 feet. In many places the clay has been consolidated, by the infiltration of carbonate of lime derived from springs, into a tough rock, containing recent land and freshwater shells, such as *Helix*, *Limnæa*, *Neritina*, etc., which may be found still living in large numbers in the cultivated flats near the banks of the larger rivers. Numerous pisolitic granules of iron oxide are scattered freely through the clay, and in some places the amount of iron becomes so great, that the rock has been used as an ore for smelting.

The carbonate of lime leached out from the rock is partly carried off by the streams, and partly redeposited in their channels, forming thick beds of calcareous tufa. Wherever rocky scarps are found, they too are usually covered with a thick curtain of the same material. The "natural bridges" in the Gokteik gorge are to a great extent formed of it, and its cavernous nature has proved a considerable obstacle to the engineers engaged on the construction of the great viaduct there. In many of the rivers it forms regular dams or weirs, stretching horizontally across the stream, and so regular that they might be thought to be artificial. The presence of this calcareous tufa in the streams, although it adds much to their picturesqueness, is a great drawback from a geological point of view, for the rocks are entirely concealed by it in most cases, and nothing can be seen of them. The deposit is sometimes of great thickness, as, for instance, in a spur cut through by the railway between Lwekaw and Kyinsi, on the Namsim, where the cuttings show it to be at least 50 or 60 feet thick.

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[1] Records, G. S. I., Vol. XXIV, Part 2, p. 105, et seq.

Beds of recent alluvium are not often met with in the portion of the plateau which I crossed. There are a few narrow patches of it in the valleys of the larger rivers, notably in the valley of the Nam Tu (Myitnge) near Hsi Paw, where there are also a few patches of older alluvium containing large well rounded boulders, mainly derived from the red sandstones, on the lower slopes of the surrounding hills, probably the remains of old river terraces.

IV.—STRATIGRAPHICAL DETAILS ALONG THE ROUTE TAKEN.

From Sedaw, a small village at the foot of the hills about 15 miles to the south-east of Mandalay, the line rises by a series of zigzags, directly up the hillside, to a height of about 600 feet above the plain, passing through the dark blue and grey limestones of the Sedaw beds. The dip of these at the foot of the ascent is to the west-south-west at about 50 degrees; in fact, the outer edge of the plateau here is a dip slope. The direction of dip does not, however, remain constant for more than a short distance. Between the second and third reversing stations it is at first northerly, and then again south-westerly, always at fairly high angles. The folds, of which only small portions can be seen at one time in the cuttings, are probably in the form of domes of no great lateral extent, so that the direction of dip varies greatly within short distances. Just below the third reversing station, at a height of about 600 feet above the plain, the red crinoid beds are met with. The actual line of contact is concealed, and the two formations are dipping in quite different directions, that of the limestones being north at about 20 degrees, while the red crinoid beds dip east at 45 degrees. In spite of this difference of strike, I do not think that there is any unconformability. The whole series probably forms an anticlinal with its axis nearly north and south, but the general direction of the fold is obscured locally by minor cross-folds.

The red crinoid beds are well seen between the third and fourth reversing stations, where there are some deep cuttings through them. The only fossils I could find in them, are small fragments of crinoid stems and one badly preserved *Orthoceras*, the whole interior of which is filled with white crystalline calcite, but the position of the siphuncle is still discernible.

These beds pass upwards into a thick series of flaggy limestones in regular layers, separated by bands of clay or shale, very well exposed in the cuttings between the 18th and 20th miles. Near the base of these, two or three bands of red shales are intercalated, exactly similar to the thick crinoid beds below and also containing crinoid stems. Higher up, at the 19th mile, numerous specimens of *Orthoceras* occur in a small quarry close to the line; the dip here is northerly at about 11 degrees. In a cutting immediately above this some carbonaceous shales are interstratified with the limestones.

These limestones and shales are also well seen along the cart-road, some few miles to the south, in the neighbourhood of Nyaungbaw. At the 22nd mile, about a mile and a quarter below the rest-house, they contain fragments of a large *crinoid*, some of the specimens showing the calyx with the arms attached, also numerous specimens of *Orthoceras*.

On the railway these beds extend to about the 20th mile. They are greatly disturbed and faulted, and the same beds may be repeated more than once. Above the 20th mile there is a low, but well-defined, scarp, about 150 feet in height, at the top of which is a level plateau in which the village of Zebingyi stands. The railway skirts this to the north, exposing good sections. At the base a band of dark grey limestone, rather nodular, is seen containing numerous specimens of *Orthoceras* and an occasional *Trilobite* (No. 5). The dip here is to east-north-east at about 15 degrees. This band is followed by black calcareous shales (No. 6) containing numerous specimens of *Graptolites*, matted together on the surface of the layers. With these occur enormous numbers of a small fossil, the nature of which I was at first unable to determine. They are in the form of minute spines, from about ¼ to ¾ inch long, and ⅙ to ⅛ broad. A furrow runs for about half the length from the broader end down the centre, and the whole fossil is beautifully ornamented with regular transverse striæ. I thought that they might be a species of *Theca* or *Hyolithes*, but I find that they correspond most closely to *Tentaculites elegans* (Barr.). The figure given in Vol. III, Pl. 14, of Barrande's Silurian System of Bohemia might have been taken from one of the Zebingyi slabs. These fossils belong to the stages G and H or upper silurian of Barrande's classification, and with the *Graptolites*, which appear to be all confined to the genus *Monograptus*, afford, I think, sufficient evidence that these beds belong to that epoch.

The black shales at Zebingyi are followed by white, or light grey limestone (No. 7), in which I could find no fossils in this locality, but a few ill-preserved fragments of *crinoid* stems. The surface of the Zebingyi plateau is formed of this rock. The limestones, where first seen, are dipping in the same direction, *i.e.*, easterly, as the graptolite beds, and apparently rest conformably upon them.

Proceeding along the railway to the east of Zebingyi station, the white limestones are seen for about a mile dipping in a north-westerly direction. It is thus evident that the rocks underlying the plateau form a synclinal. About the 23rd mile the graptolite beds are brought up again, dipping N. 40. W. at an angle of 15 degrees. They are succeeded below, by a band of soft yellow shales with concretionary bands of hard limestone (No. 5). Here *Trilobites* are more numerous than in the Zebingyi scarp, but they appear to occur only in the soft beds, and are difficult to preserve. The limestones immediately beneath contain large numbers of *Orthoceras*, but mostly in a fragmentary state.

Beyond this the line runs by a succession of severe gradients up the side of a steep ridge, on which the lower flaggy limestones and shales (No. 3) are well seen. They are greatly disturbed and frequently dip at high angles, generally in a north-westerly direction. They appear to contain nothing but a few *crinoid* stems. About a couple of miles from the base of the ridge the red crinoid beds (No. 2) appear beneath the flaggy limestones, but are not well seen, as the latter quickly bend over again to the east.

The axis of the Zebingyi synclinal appears to be inclined to the north, so that on the cart-road about three miles to the south of Zebingyi the graptolite and trilobite beds are not met with, but the whole space between Nyaungbaw and the foot of the high ridge east of Zebingyi is occupied by the flaggy limestones and shales (No. 3) with *Orthoceras*. At the foot of the ridge the red crinoid shales are again brought to the surface, dipping in a west-north-west direction. At first they occur as bands of only a few feet thick in the limestones, exactly as in the section above the fourth reversing station on the railway; but a little higher up, between the 25th and 26th miles, there is a very thick band of them. It was at this locality that Dr. Noetling discovered the lower silurian cystidean *Echinosphærites Kingi*, and numerous spcimens may be found along the road a little below the 26th mile, associated with *Orthoceras* and fairly well preserved *crinoid* stems.

These beds are succeeded below by hard limestones, probably the same as those exposed in the zizgags above Sedaw (No. 1), which extend to the crest of the ridge to within a mile of Pyinsa village, from which Dr. Noetling named the series.

Immediately after crossing the crest of the ridge, and within a few yards of the hard limestone, the soft upper silurian trilobite beds are again found, highly disturbed, but with a general north-easterly dip. They are evidently faulted down against the lower silurian limestones. To the east, close to the village of Pyinsa, the graptolite beds are formed overlying them, in the bed of a small stream, that crosses the road immediately north of the village, and dipping steadily to east-north-east at an angle of about 15 degrees. The road here turns to the north and runs along the crest of the ridge following the strike of these beds, which are exposed at two or three places, *viz.*, near the 29th mile, and again about a mile north of Thondaung rest-house near mile 32. A short distance beyond this, at the village of Thingunaing, they pass under the upper palæozoic white limestones, which form another well defined scarp to the east of the road, but they are again well exposed in the same strike in a cutting on the railway about half a mile above Thondaung (Waboye) station. Well preserved specimens of *Graptolites* and *Tentaculites elegans* with a small bivalve, may be obtained in the spoil pits along the line at this locality.

The Pyinsa fault appears to die out in this direction, passing into an ordinary anticlinal fold, which is well seen in the cuttings on the ascent between Zebingyi and Thondaung station. The railway runs practically along the crest of the fold.

Above Thondaung station the graptolite beds pass beneath the white sandy limestones (No. 7), which extend all the way to Maymyo, with a general easterly dip, and form the plateau on which the station is built. In some of the cuttings casts of small gastropods are found in the limestone, but for the most part it appears to be unfossiliferous.

To the north of Maymyo the white limestones extend for about two miles to the foot of a range of low-rounded, jungle-covered hills.

Sections of the rocks composing these are seen on the path to the village of Naungkangyi and they are found to consist of soft sandy shales, somewhat similar in appearance to the trilobite beds, but containing a very different assemblage of fossils. No *Graptolites* or *Trilobites* were found in them, nor could I find any specimens of the small *Tentaculites elegans*, whose remains are so characteristic of the graptolite beds. Instead of these there are numerous specimens of *Orthis* and of plates of a small cystidean closely resembling *Mimocystites bohemicus*, a Caradoc or Bala fossil. These beds dip to the south-east at angles of 40 to 50 degrees and the white limestones are apparently faulted down against them.

To the east of Maymyo the white limestones extend both along the railway, and cart-road to, and beyond the village of Wetwun. Casts of small gastropods occur in a spoil-pit on the railway about five miles from Maymyo. Just beyond Wetwun, at the 55th mile on the cart-road, a band of argillaceous shale or Fuller's earth is badly exposed at the side of the road, containing numerous fossils, including many lamellibranchs, casts of a small *Orthis* or perhaps *Atrypa*, and a fossil, badly preserved, resembling *Theca* or *Hyolithes*. A *Fenestella* also occurs. The relations of these shales to the limestones cannot be made out, but they probably form a band in the latter.

Beyond Wetwun nothing is seen along the road except an occasional, very small outcrop of white limestones, until the 73rd mile is reached, near the village of Kyaukkyaw, where the railway and cart-road cross a well-defined scarp running north and south. Here there is a deep cutting through the limestone, in which the intense crushing which the rocks have undergone, can be well studied. Slicken-sided surfaces are numerous, highly polished and covered with a thin red glaze, and the body of the rock is so crushed that it breaks into small fragments when struck with a hammer—a condition made use of by the railway engineers, who convert the rock, at the expense of a few charges of dynamite, into heaps of ballast, ready broken, for the railway.

Immediately to the west of the deep cutting, there is a smaller one, in which some highly fossiliferous shales (No. 8) are exposed. These dip to the east and appear to pass under the limestones, but as I found precisely similar fossils in some shales, to be described presently, near Hsi Paw further to the east, where they occur at the top of the limestones, it is probable that they are faulted down against the latter in the Kyaukkyan ridge. The fossils in the shales include numerous casts of *Pecten*, a small *Conocardium*, and other lamellibranchs, which have not yet been determined. The shales rest upon hard dark blue limestones in which fossils are numerous, which appear only as weathered sections on the surface of the rock.

Beyond Kyaukkyan a plateau formed of the white limestones extends *viâ* Nawnghkio to the edge of the Gokteik gorge, where the rocks bend over and plunge into the gorge with a steady easterly or east-south-east dip of about 30 degrees. The rocks are greatly crushed and full of small faults and gliding planes. On the opposite (north-east) side of the gorge the cliffs are entirely composed of the white limestones, which must be of enormous thickness unless they are repeated by faulting. Near the bottom of the gorge the rocks are almost entirely covered with a thick deposit of cavernous calcareous tufa of which the well-known "natural" bridges are to a great extent composed.

The cart-road crosses the gorge some miles above the railway-crossing, and the cuttings along it afford good sections of the rocks beneath the white limestones. For the first two or three miles limestone is seen at intervals ; then at the short cut above the eighty-fourth mile there are some soft yellow, sandy beds, containing badly-preserved fragments of *crinoid* stems, probably the representatives of the trilobite beds of Zebingyi (No. 5). These are again exposed on the eastern side of the gorge, just above Chaungow rest-house, at mile 88½, where I found specimens of *Encrinurus punctatus* in them, as well as numerous casts of *Orthis* and *Petraia*. These are followed beneath by grey, sometimes purple, calcareous shales and limestones, which are well exposed on the zigzags along the road, between the 84th and 86th miles. In places, notably at mile 85, these rocks are crowded with fossils, mostly casts of *Orthis* and *Strophomena*. The cystidean plates found in the shales north of Maymyo also occur here in considerble numbers, and I think there is no doubt that these beds are identical with those of Naungkangyi (No. 4). The shales and limestones dip east-south-east at about 30 degrees and continue to the bottom of the gorge. They are seen again on the ascent near Chaungzow rest-house, but on this side I could find no fossils in them.

The same beds occur some miles higher up the western branch of the river that flows through the gorge, on a path that crosses it due north of Nawnghkio, but are very badly exposed and the fossils are quite fragmentary.

Returning to the eastern side of the gorge the yellow trilobite beds above Chaungzow are found to be followed by the white limestone. I searched for the black graptolite beds here, but could find no trace of them. From the edge of the gorge the limestones extend for a long distance along the road; in fact, hardly any other rock is seen for some twenty miles. In a spoil-pit on the railway, two miles north of Gokteik station, numerous casts of small gastropods and a little bivalve probably a *Pterinea* occur in the limestone, and within a few yards there is a small outcrop of argillaceous shales, similar to those at Wetwun, containing a few fossils among which a *Lingula* (?) is most common. Here again the relations of the shales to the limestone cannot be made out. A short distance further up the line, at mile 89½ on the cart-road, the shales and limestones are seen in contact, but are greatly disturbed and evidently faulted against each other. Between Pyaunggaung (mile 105) and Lwekaw (mile 116) on the cart-road, nothing but limestone is seen, the road running along the strike of the beds, which dip generally to east-south-east. But on the railway, about five miles beyond Pyaunggaung, there is an outcrop of very soft sandy beds, full of fossils, including *Fenestella retiformis* in large numbers, *Encrinurus punctatus*, *Strophomena*, *Orthis*, and many *crinoid* stems. These beds are quite isolated, but they dip apparently beneath the white limestones. Further on, about three miles west of Lwekaw, a band of shale occurs in the limestone, containing minute bivalves and fragmentary plant remains. Some of the shales are here distinctly carbonaceous.

Beyond this nothing further is seen, up to the 123rd mile on the cart-road, about a mile west of the village of Kyinsi. Here some light grey shales with nodular bands of blue limestones are exposed in the railway cuttings, containing the same assemblage of fossils as at Kyaukkyan. The shales rest upon thick dark blue concretionary limestones, the whole dipping north-north-east at 20 to 30 degrees, and fossils also occur in the limestones, only showing as at Kyaukkyan on the weathered surface of the rock. The white limestone occurs in the jungle on the southern side of the cart-road, which runs here close to the railway, and apparently dips beneath the blue limestone and shales, but the actual contact is not seen.

A few hundred yards to the east of the fossiliferous shales, but separated from them by a blank space, a very different series of beds is seen. These are soft red and green clays interstratified with thick beds of soft red and brown sandstones. Where first seen they are dipping north at from 40 to 50 degrees, but on following the beds along the railway beyond the bridge over the Namsim, they are found to be greatly disturbed and folded. To the east of this the valley opens out into a broad level plain covered with rice fields, through which the Nam Tu (Myitnge) flows, and no rocks are visible. Where the hills close in again, however, to the east of Hsi Paw, the red sandstones and shales are again met with, thrown into narrow folds striking north-east along the valley of the Nam Tu, and very well exposed in the railway cuttings through the spurs bordering the river. The sandstones are occasionally hard enough to form an excellent building stone. They occupy the whole valley of the Nam Tu up to its junction with the Namyao, or Lashio river, and continue up the valley of the latter to about five miles above its junction with the Namma below Se Ing rest-house, where they are faulted against the white limestones. The red sandstones are also seen on the cart-road between Hsi Paw and Kontha rest-house, but no good sections are exposed. At Se Ing the limestones form a narrow gorge through which the river flows for several miles.

About a mile above the junction of the Namyao and Namma, I found in one of the railway cuttings a few fragmentary fossils in the red beds, mostly lamellibranchs. They have a certain resemblance to some of the fossils in the Kyinsi shales and it seems probable that the latter with the red sandstones form one series. From a cursory examination of the fossils it appears not unlikely that the whole sequence may be devonian. Fossils must be very rare in the red beds, for although I searched carefully I found none except in this one locality.

Higher up the valley of the Namyao, limestone is the prevailing rock, but the river runs along the boundary between it and the red sandstones, and the latter are occasionally seen in the railway cuttings. The actual junction is not seen anywhere, and I could not find the Kyinsi fossiliferous shales, but the whole country is covered with dense jungle and soft beds of that description are apt to be concealed.

The Namyao in this portion of its course affords many fine examples of the natural dams or weirs of calcareous tufa already mentioned. They succeed each other at intervals of a few hundred yards all the way up the river and are of very various heights, from a few inches up to several feet. Some five miles above Se Ing they are especially numerous and resemble a huge salmon ladder. At the top is a very fine waterfall the whole face of which is covered with tufa. These dams take the place of the rapids in an ordinary river, but it is difficult to see how the growth is started, for one would expect it to be washed away as quickly as it was formed in the broken water of a rapid. From the appearance of the fresh deposit, which is often of a vivid green colour, I suspect that it is to a great extent organic in origin and that it is built up by minute algæ much in the same way in which a true coral reef is formed.

The white limestone continues along the valley of the Namyao to, and beyond Lashio; in fact, it extends as far as the Salween, but it is generally concealed by recent clays. There are no railway cuttings along this portion of the route and very little of the rocks can be seen. About four miles to the north of Lashio, where the road to the Kunlon ferry crosses the Namyao, a small patch of shale crops out containing very ill-preserved fragments of plants; and near the village of Mongyaw at the head of the valley some minute rounded bodies occur in the limestone which may be organic, but beyond these I could find no fossils whatever. The red sandstones appear cupping the hills to the south of the valley between Mongyang and Mongyaw, but do not contain any fossils, so far as I could see. Beyond Lashio the road to Kunlon runs practically along the strike of the rocks and nothing can be seen of the formations lying to the north or south of the route.

Notes *on the* Geology *of the* country *along* the Mandalay-Kunlon Ferry Railway Route, Upper Burma, *by* P. N. DATTA, B.SC., (London), F.G.S., *Deputy Superintendent, Geological Survey of India.*

The projected railway; its general direction from Mandalay.

The projected line of railway from Mandalay to the Kunlon Ferry on the Salween in Upper Burma, passes through Maymyo, the hill station of the Lieutenant-Governor of Burma, Thibaw (Hsi Paw), and Lasbio, the head-quarters of the Superintendent of the northern Shan States. There is a cart-road from Mandalay as far as Lashio, and the railway has followed close to this old cart-road as far as Thibaw. From Lashio there is no cart-road, but only a mule-track as far as the Kunlon Ferry.

Extent of route traversed.

This line of railway, the first section of which, *i.e.*, from Mandalay to Maymyo, a distance of about forty miles, was to be opened on the 1st of April this year, runs from Mandalay in a general north-east by east direction, the first fifty miles or so being in the Mandalay District, and the rest in the adjoining northern Shan States. As I, however, went only a few miles beyond Thibaw (Hsi Paw), *i.e.*, about 140 miles by the cart-road from Mandalay, my examination of the ground extends therefore to the neighbourhood of Thibaw only.

From Mandalay to Tonbo, which is ten miles south-east of Mandalay, the railway runs over a plain which shows no exposures of solid rock, the hills commencing near Tonbo.

Extent of plain eastwards of Mandalay.

Due east of Mandalay the plain extends for about 5 miles or less, the limestone composing the foot hills here being a continuation of those seen in the neighbourhood of Tonbo, the beds striking here very nearly north and south.

Mandalay Hill: its probable age.

The hillock called Mandalay Hill just north-east of the Mandalay Palace is composed mostly of crystalline limestone, the bedding being distinct and the rock in many places quite unaltered. The strike is north by west, south by east, with a high dip to the eastwards; that is to say, the strike of these beds is identical with that of the beds forming the foot-hills to the east. Although the identity of the dip

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and strike of the Mandalay Hill limestone would point to its belonging to the same sequence of beds as the limestone of the foot-hills to the east, still in view of the altered (crystalline) condition of the rock and the non-discovery yet of any fossils in them, it would seem to be best to leave the question of its age yet open and to say only that the limestone of the Mandalay Hill is probably of the same age as the limestone of the foot-hills.

Previous observations; Dr. Noetling's classification.

Dr. Noetling, Palæontologist to the Geological Survey of India, had gone over this ground along the Mandalay-Lashio cart-road, and the result of his observations was published in the Records, Geological Survey of India, Vol. XXIV, Part 2, page 99. The rocks were classified by him into—

1. Gneissic formation.
2. Submetamorphic formation.
3. Palæozoic group ranging probably from the Cambrian to the upper silurian system.
4. Red sandstones of undetermined age.
5. Tertiary formation.
6. Alluvial formation, probably younger miocene.
7. Volcanic rocks; porphyry of unknown age, granite of gneissic age.[1]

Of these formations, Nos. 1, 2, and 7 do not at all occur along the track gone over by me. Alluvium does occur here and there in the neighbourhood of streams, but I did not stop to map it, as it would have been sheer waste of time to attempt this with the maps we had at our disposal. The ground examined by me included principally the beds grouped above as No. 3 and also portion of No. 4. Whether any of the beds occurring here are tertiary can only be determined by the fossil contents, but no tertiary fossils were found by me.

Dr. Noetling's grouping of the limestones.

In the above paper Dr. Noetling classifies all the limestone beds, commencing from those that form the foot-hills, *i.e.*, the hills forming the westernmost border of the northern Shan plateau, extending to Pyintha and further east across the Shan plateau, into two divisions:—

1. Mandalay limestone without fossils (lower);

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[1] Rec., G. S. I., Vol. XXIV, Part 2, page 103.

2. Pyintha limestone with fossils of lower silurian epoch (upper);

and in the lower division is included all the limestone composing the foot-hills, while the beds occurring in the neighbourhood of Pyintha formed the Pyintha beds, the lower division or Mandalay limestone being in this classification characterized by the absence of fossils.

Hills by Tonbo fossiliferous.

I commenced work at Tonbo at the very edge of the hills forming the Shan plateau, and the first fossils here were obtained at ½ to ¾ mile north by west of Tonbo village. In fact all the hills atout here, *i.e.*, to the N., N.E. and E. of Tonbo, extending as far as Sedaw village to the east, close to where the Mandalay-Kunlon Railway leaves the plains and begins its first zigzag hilly ascent, were found abundantly fossiliferous, the only drawback being that in many cases the fossils could only be seen in sections, in casts or in fragments, rendering their collection and identification difficult or impossible. Fossils are also met with in great numbers as one goes up the hilly foot-track from Sedaw towards Zibingyi.

Dr. Noetling's grouping of the limestones no longer tenable.

As thus the limestones of the foot-hills, beginning with the very edge of the hills skirting the Mandalay plain, are found to contain fossils, Dr. Noetling's division of "Mandalay limestone without fossils," as applied to these rocks, is no longer tenable. As for the series of "Pyintha limestone:" the fossils of his "Pyintha" beds are not of a character or kind to entitle the beds to the rank of a separate division or series except and until we are in a position to undertake the minute sub-division of the different series of beds, which we certainly are not yet. If they are lower silurian in age, then they but form an insignificant portion of the entire thickness of the beds, namely, from near Tonbo to the neighbourhood of Zibingyi, which belonging as they seem to do to the lower silurian epoch, will thus include the Pyintha beds as part and parcel of them. Thus the divisional name of Pyintha limestone cannot also be retained.

There is another reason why, in view of the fossils found this season in the beds in and about the village of Pyinsa (Pyintha), the name of "Pyintha" limestone could not be appropriately retained, and it is that the Pyinsa village actually stands on beds which occupy a higher horizon (*i.e.*, probably of the upper silurian age) than the Echinosphærites beds which are of the lower silurian epoch. If the term "Pyintha" has now to be used as a group-name at all, it can now only be properly used to designate the trilobite and graptolite-bearing beds on which the village is actually situated, and not beds at a distance with a different set of fossils.

Why local name of "Tonbo" preferable to "Mandalay".

The name of "Mandalay" might be retained for the group of rocks which I have designated as "Tonbo series," representing the limestones of the foot-hills near Tonbo, Sedaw, etc. But the local name of "Tonbo" seems preferable for several reasons. Besides, by "Mandalay group" Dr. Noetling included all the beds *up to the base* of the Echinosphærites beds occurring between Nyambaw and Pyintha, the Echinosphærites beds being grouped distinct and as "Pyintha" beds. But my Tonbo series *includes* the beds underlying the Echinosphærites beds as well as the *Echinosphærites beds themselves.* So the retention of the name of "Mandalay" as a group-name might introduce confusion. So it seems best to represent the series under the designation of "Tonbo" beds.

From their position in reference to his Pyintha group, the "Mandalay Limestone without fossils" was looked upon by Dr. Noetling as Cambrian (Records, Geological Survey of India, Vol. XXIV, Part 2, page 104). From the fossils collected, however, this season, Dr. Noetling is now of opinion that they are silurian in age.

Nature of the country along the route: Along the railway.

The railway line, as already indicated, passes over the Mandalay plain as far as Tonbo, a distance of ten miles to the south-east from Mandalay. But though the hills commence here, the railway runs for another three miles, *i.e.*, as far as Sedaw, over level ground. At Sedaw it begins its first zigzag ascent of the hills attaining a considerable height at Zibingyi over steep gradients, and from Zibingyi it still goes on ascending until it reaches, at an elevation of over 3,000 feet above the sea-level, the station of Maymyo, the highest point on the Mandalay-Kunlon Ferry line. From Maymyo the line follows a north-east by east course along the edge of a valley as far as Wetwin ("Wenwi" of map), crossing the Kelaung stream there. From Wetwin the route passes over a low level ground—evidently the bottom of a valley, with innumerable streams running to the south-east, until Kyaukkyan is reached, where ascending a slightly higher ground it runs on to the Gokteik gorge. From the eastern side of the gorge the railway runs over a fairly level ground by Pyounggoung, and crossing the Namsim near its mouth and keeping in the valley runs on along the right side of the river by Thibaw (Hsi Paw) and past it.

Along the cart-road.

While the railway line begins its ascent of the plateau near Sedaw, the cart-road from Mandalay to Lashio *en route* to Kunlon, ascends the table-land about a mile and a half west of Nyaumbaw, that is, at about 4 miles south by west of the Zibingyi Railway Station. A couple of miles east of Nyaumbaw or one mile east of Zibingyi station, there is a sudden rise in the ground, looking like a hill range from the west, running north and south, but really due to the elevation of the ground with a change of dip of the beds to the west. Up to this point (Nyaumbaw), the cart-road had kept a roughly south-east course from Mandalay, but from here it begins to run north-east, keeping all along fairly close to the railway line, and this direction is maintained up to and beyond Thibaw.

Relation of strike of beds with the trend of the hill-ranges.

Among the foot-hills in the neighbourhood of Tonbo, Sedaw, Kwetnepah, etc., it is obvious that the direction of the hill-ranges is coincident with that of the strike of the beds. Further inwards into the plateau, *i.e.*, to the eastwards, the map being of an unreliable character, it becomes difficult to tell how far this agreement holds. By Tonbo and Sedaw the beds strike north by west, south by east, with a high general dip to the east. And although there may be noticed occasional dips to the west, due to folding, it is quite clear that as a general rule the series is ascended as one proceeds from the foot-hills at the western border of it eastwards across the plateau.

It will perhaps be best if the rocks in the different localities were at first separately noted in their proper order as one proceeds from west to east, their relations with one another being indicated later on. Following this plan I will begin with Mandalay itself.

Mandalay Hill.

From the agreement of the dip and strike of the beds of limestone of this hill with those of the limestone of the hills to the east, the Mandalay Hill limestones are evidently of the same system of rocks forming the hills to the east.

Hills near Tonbo.

Tonbo stands at the very border of the foot-hills of the Shan plateau. The hills are composed of a generally thick-bedded limestone, the rock varying in colour from blue to light to dark grey and to bluish grey. That the rock has been subjected to considerable pressure is proved by the presence of innumerable irregular cracks and jointing, often slickensided and by the rock being in places semi-crystalline and brecciated. While the blue limestone, often semi-crystalline, was found here to weather with a black crust, the greyish limestone weathers yellow. North of the village, even at the very foot of the hills, the limestone is clearly seen dipping at 60° to 70°, and even at a higher angle, to the eastwards.

Locality for fossils, north-west of Tonbo.

The first fossils here were obtained at half a mile north by west of the village, at the very edge of the hills, about thirty feet from the level of the fields. From three-fourths of a mile to one mile, on the slopes of the hills facing the plains, north by west of Tonbo village, corals and bivalves, often fragmentary, are abundantly seen on the weathered surfaces of the rock. Foraminifera, corals, sponges, and minute *crinoid* stems are also observable here. Here some big casts of bivalves, which were difficult to identify, were also seen.

Fossils east by north of Tonbo.

Another good locality for fossils in this neighbourhood is about 1¼ miles east by north of Tonbo. Fossils are best collected here either on the weathered surfaces of the beds or on the detached weathered fragments strewn about among the beds on the slopes.

Kwetnepah.

This village is situated on the Myitnge river, about four miles south-east of Tonbo. In marching from Tonbo to Kwetnepah, exposures of limestone are met with on the road a mile past Ongyaw. The rock is of the same character as north and north-east of Tonbo and also with a similar dip and strike. Among the fossils found here the coral at least is identical with that found north of Tonbo. That the hill-ranges near Kwetnepah on the Myitnge are a continuation of those of the Tonbo is evident from the identity of strike of the beds and of the hill-ranges in the two places and also that of fossils. The range that is seen south by east of Kwetnepah, on the left bank of the Myitnge, and catches one's eye from its rugged bold outline from a considerable distance, is, there can hardly be any doubt, of the same age as the hills near Tonbo.

Fossils.

The limestones forming the range half a mile east of Kwetnepah are also remarkably fossiliferous. Bivalves, corals, sponges, gastropods, etc., abound; while some distance up the slopes, at a point one mile north-east by east of the village, some beds seemed made up of masses of a coral (Strombodes ?). Three or four kinds of corals were noticed on the slopes, one of these at least, a Syringopora, being apparently identical with that found near Tonbo. The rock is light to dark grey and bluish in colour, dipping east by north at 85°.

Sedaw.

Argillaceous shales.

Fossils.

While in the neighbourhood of Tonbo, Ongyaw and Kwetnepah the hills seemed to be made up of nothing but limestones, varying in colour from light to dark grey and to blue, it is for the first time near Sedaw that one meets with argillaceous shales interbedded with the limestones. About half a mile north-west of the village one can see occurring in the shale harder lenticular patches of a calcareous shale or shaly limestone, these patches often yielding fossils. Strike of the beds here is north-west, south-east. Almost due north of the village, half a mile or so from it, some reddish shales are seen. Among the fossils found here are coral and echimodermatous remains, besides sections of shells.

Valley north-east of Sedaw.

A tributary from the north falls into the main stream at three-quarters of a mile north-east of Sedaw village. The sides of the valley show thick-bedded limestone, but that the centre is occupied principally by shales, though none is to be actually seen, is evidenced by *dèbris* found in the bottom of the valley.

First ascent of railway up the hills.

Over an anticline.

One mile due east of the Sedaw village is the little railway station (Sedaw) at the foot of the plateau, and here the railway begins its ascent of the hills. This station is on the thirteenth mile on the line. At the foot the limestone, well exposed in the cuttings, is seen to dip W. 15° S. at 50°; but going up the slopes directly above this point one finds the beds near the top dipping at 35° to E. 10° N., showing that here the limestone beds form a sharp anticline. Looking from this high point northwards, one notices an exposure of a very red coloured rock towards the head of the valley of the tributary stream which falls into the

Red shales by the 17th mile.

Sedaw river three-quarters of a mile north-east of Sedaw. There is little doubt that this red rock is a portion of the synclinal fold of the red shale which is well exposed on the railway about the 17th mile (see Plate, Fig. 1). The railway on leaving the Sedaw station goes up in a very zigzag line as it first ascends, and follows a general south-east course for some distance, then turns north-east and shortly reaches the third and fourth reversing points between the seventeenth and eighteenth mileposts. Here is exposed a thickish mass of bright red calcareous shale, dipping E. 10° N. at 50° to 55°. The red shale is highly calcareous, much pressed and indurated and often exhibits a shining lustre along the lamination planes. Occasional minute stems of crinoids are all that could be obtained from these beds in the shape of fossils.

Fossils.

It is noticeable that if one comes up from the foot of the hills along the new railway cuttings one does not come across or see a single indication of a fossil, however closely one might examine the fresh faces of the rock exposed in the cuttings, leading one to suppose that these beds must be perfectly devoid of organic remains. But let one follow the old foot-track that ascends the same hill to the north of the railway line—the old footpath leading from Sedaw to Zibingyi—and one is agreeably surprised at the quantities of fossils one meets with on the very foot-track on the weathered surfaces of the rock. *Euomphalus* is specially abundant, with *Orthoceras*, *Gomphoceras* (?), etc., etc.

The beds as traced towards Zibingyi.

The red shales just above referred to, pass eastwards, *i.e.*, upwards, into mud-coloured argillaceous shale. This argillaceous shale is in places blackish and exceedingly hard, as seen by the 18th mile. From this point the Zibingyi railway station lies about two miles east by north in a direct line, but the actual length of the railway between these points is four miles. Proceeding towards Zibingyi from the eighteenth milepost various kinds of limestone are passed over, all dipping eastwards and rather at a high angle. Occasionally a bed or two of limestone, perfectly black in colour, is met with which might be taken for coal from a distance. About midway between the 18th mile and the Zibingyi station argillaceous shales are seen, these often being reddish in colour and with concretionary masses of limestone, grey or flesh-coloured, and fossils such as *crinoids*, *Orthoceras*, etc., have been found in them. Nearer Zibingyi, these red shales and clays with calcareous concretions are succeeded by limestone beds which on approaching Zibingyi assume a low dip.

Zibingyi syncline.

About 1½ miles west of Zibingyi station, fragments of trilobites are met with together with conical little bodies beautifully sculptured transversely, which are most probably Styliolas. Next after passing over some limestone and argillaceous shales were found monoprionidian graptolites, with some minute bivalves, etc. For a mile west of the station hardly any exposures of rocks are visible; but proceeding east along the line and past the station, some thin-bedded limestones and soft yellow shales are met with one mile east of the station. These dip, however, to the west and contain trilobites and graptolites, together with the Styliolas and bivalves. Thus there is a little syncline here with Zibingyi station as its centre.

By the cart-road from Tonbo.

Red shales.

Nyaumbaw.

Specimens of a large crinoid.

If one proceeded by the cart-road from Tonbo, which is on the thirteenth milepost on the Mandalay-Lashio cart-road, he would meet with thick-bedded limestones with corals, etc., up to a point 1¼ to 1½ miles north-east of Kwetnepah. A little beyond this point is the seventeenth milepost (on the cart-road), and beyond this is an exposure of a red calcareous shale, which is evidently an outcrop of the same rock as is exposed about the 17th mile on the railway. From here the road keeps a zigzag south-east course for some distance, often showing the same red and grey argillaceous shales, with limestone beds much disturbed and folded. The cart-road ascends the plateau in a zigzag manner 1½ to 1¾ miles west of Nyaumbaw. A little over a mile west of the Nyaumbaw Inspection Bungalow, which is on the twenty-third milepost on the cart-road, or to be precise, between the fifth and sixth furlong posts past the 21st mile, I found, in a light grey limestone with argillaceous shale, some fine specimens of the stems and arms of a large crinoid, with Orthoceras, etc. The rock about here is a grey thinnish-bedded limestone with calcareous and argillaceous shales, the shaly limestone being sometimes of a flesh colour. By the police station and the Priests'

Locality of Echinosphærites.

House at Nyaumbaw a limestone which unweathered looks not unlike a gneiss, is associated with reddish shales with calcareous concretions and yields abundance of rather small crinoid stems and Orthoceras. Between the twenty-fifth and twenty-sixth mileposts, that is, about two miles east of Nyaumbaw, and at the foot of the rising ground, the rocks are also well exposed, being a red shale with calcareous concretions interbedded with thin-bedded limestone, and in these shales were found *Echinosphærites*, *Orthoceras*, crinoid stems, etc., and with these, also some other fossils rather of large size, some measuring four to five inches across, occur. But what they may be it has not been possible to determine yet.

The rise in the ground here corresponds to a change in the dip, that is to the western direction, of the beds, this line of elevation being the continuation of the high ground also seen one mile east of the Zibingyi station.

Pyinsa and neighbourhood.

Zibingyi beds.

Proceeding up this steepish rise along the cart-road, the level ground is reached ¼ to ¾ mile west of Pyinsa (or Pyintha) (between the twenty-seventh and twenty-eighth mileposts) and here the beds are seen resuming their dip again to the east. A short distance before Pyinsa is reached, soft yellowish shales with trilobites and Styliolas are met with dipping east. A little to the south-east of the village is exposed, on a stream-bed, a dark grey to blackish limestone with graptolites. Coming back again to the cart-road and going north one comes upon, at a point between the first and second furlong posts past the 29th mile, that is, about 1¼ miles short of the Thongdaung Inspection Bungalow, and in the very middle of the road, some thin-bedded black limestone which has only to be turned up to show the graptolites they contain, being evidently an outcrop of the same beds as are seen on the stream-bed south-east of Pyinsa. From here hardly any exposures are seen till the sixth furlong post after the thirty-first milepost is reached, when some yellow shaly clay containing trilobites and Styliolas are met with. Beyond the village of Chingenah (on the 32nd mile) mud-coloured argillaceous shales interbedded with limestone bands are seen, dipping east at 20° and evidently overlying the series of beds containing trilobites and Styliolas just seen to the south. As from this point beds higher in the sequence are met with as one proceeds along the cart-road towards Maymyo, we might deviate here a little from the cart-track and inquire if the trilobite and graptolite bearing beds of Zibingyi are to be seen along the railway line east of Zibingyi. They do appear on the line about one-third mile north of Thongdaung station and are traceable to a point a little distance south of Waboye village. The beds here have yielded *trilobites*, *graptolites*, aud Styliolas with a fair sprinkling of bivalves, etc. Thus the trilobite and graptolite beds which form a small syncline about Zibingyi occupy also two other areas in the neighbourhood, namely, one about the Pyinsa (Pyintha) and Thongdaung villages and the other between the Thongdaung Railway Station and the Waboye village. As I was directed to march rapidly through this part of the country, I made no attempt to trace the boundaries of these areas.

Another area of Zibingyi beds.

As one proceeds north-eastwards either along the railway from near the village and Waboye, or along the cart-road from near Chimgenah, one meets with beds higher and higher in the series.

Red calcareous shales of seventeenth milepost on the Railway and the Echinosphærites-bearing beds.

Before noticing these higher beds, a word more might be said in reference to the Sedaw-Zibingyi section. We found a mass of red calcareous shales by the 17th mile on the railway, these being also exposed between the seventeenth and eighteenth mileposts on the cart-road. We also found certain red shales with calcareous beds well exposed between the twenty-fifth and twenty-sixth mileposts on the cart-road (about two miles east of Nyaumbaw), these coming in below the Zibingyi trilobite and graptolite-bearing beds and yielding Echinosphærites, etc. It seems to me that the first-named red shales are lower in the series than the Echinosphærites-bearing beds. For, in the first place, in physical characters they present great differences; for while the red shales by the 17th mile on the railway are highly calcareous, much pressed, and indurated, presenting a shiny lustre on the lamination planes and free from any calcareous concretionary masses in them, those on the cart-road, well seen between the 25th and 26th mileposts are, on the contrary, not calcareous (at any rate nothing like what the others are), do not exhibit the signs of the great pressure and crushing, such as induration and production of shiny lustre along lamination planes that the others show and have abundance of concretionary masses of limestone associated with them. In short, physically, the one looks quite different from the other. As for organic contents, while only minute *crinoid* stems were all that could be had from the one, abundance of remains of Echinosphærites and other fossils occur in the other.

Tonbo-Sedaw section: its age, etc.

With reference to the structure and age of the Tonbo-Sedaw section, the beds are nearly vertical, the general strike being north by west, south by east. It is also very probable that there has been some repetition of the beds through folding here. That the limestones in the neighbourhood of Tonbo are the same as those near Kwetnepah appears certain from the strike of the beds and also from similarity of fossils. Of the foraminifera, corals, sponges, crinoids, bivalves, gastropods, and cephalopods that have been found here, the greater part have not yet been determined. As the Tonbo-Sedaw section is meant to include all the beds below the Zibingyi syncline, the shaly limestone containing the rather fine specimens of the arms and stems of a large crinoid found on the cart-road between the twenty-first and twenty-second mileposts (that is, one mile west of Nyaumbaw), as well as the *Echinosphærites*-bearing red shales with calcareous concretions, come in in the upper part of the Tonbo-Sedaw section. From among the fossils found in the beds bordering the plain just north of Tonbo, Dr. Noetling identifies a coral as of the silurian age. Hence these beds composing the foot-hills near Tonbo are silurian, that is lower silurian, in age.

Zibingyi beds: their age.

Zibingyi section.—As only monoprionidian graptolites have been found in these beds and no diprionidian ones, this would seem to indicate an upper silurian age for the Zibingyi beds.

Along the cart-road.

Waboye-Maymyo Section.—After passing over the trilobite-bearing shales last seen on the cart-road a little short of the thirty-second milepost, one comes upon, in going northwards towards Maymyo, limestones with shales between the thirty-second and thirty-third mileposts. Exposures then become scarce, only bits of limestone being occasionally visible. A little past the 39th mile the road passes through a low range which shows a light grey sandstone, hard, compact, and moderately fine-grained at the foot of the hill, but getting finer-grained and quartzitic towards the top, the dip being east-30°-north at 20°. This is the first sandstone one comes across after leaving Tonbo. After a short blank another range is crossed by the cart-road at between the fortieth and forty-first mileposts, where the rock from being a white, soft, friable, flaggy sandstone, rather coarse-grained, passes up into a bluish, hard grey, compact, thick-bedded, calcareous sandstone or siliceous limestone, in places quite brecciated. Of such rocks are made up the hills one mile west of Maymyo. The dip is here 25°—30° to east-15°-south.

Along the railway.

The same section is better exposed on the railway track from Wayboye to Maymyo, the principal rock seen being a sandy limestone or calcareous sandstone with occasional intercalations of shales, all dipping eastwards. No fossils except a few minute gastropods were extracted from these beds.

The section an ascending one.

That the section is an ascending one, the dip of the beds as they are followed from Thongdaung Railway Station towards Maymyo, would clearly indicate. But if that were not quite convincing, the fact of the introduction of a new, *i.e.*, sandy, element in the hitherto perfectly purely calcareous rocks, giving a new character to the beds in this section, ought to remove all doubt. For nowhere in the Tonbo-Sedaw section does one ever meet with anything but perfectly purely calcareous beds, free from any admixture whatever of any sandy element. If the Waboye-Maymyo beds were older than the Zybingyi trilobite-bearing beds, then we should hardly expect that, while the Waboye-Maymyo beds were deposited in shallow and non-clear waters, there should not be even a trace of such impurities whatever, in the beds underlying the Zibingyi series anywhere else and in beds evidently laid down in such close proximity.

Maymyo.

Maymyo is situated on a piece of level ground surrounded on all sides by hills. On the west and south-west the hills show sandstone and siliceous limestone, dipping east by south at about 25°. North westwards the exposures are few, limestone being occasionally visible. But the hills to the south are even more disappointing, for in that direction it is difficult to come upon a piece of solid rock, a thick mass of soil overspreading the ground everywhere. Towards the north, however, *i.e.*, on the footpath leading to Naungkangyi as well as that to Tonbo, and at a point about two miles north of Maymyo, yellowish shaly clays and sandy shales are exposed and they are found to be fairly fossiliferous

Crinoid stems, Orthoceras, fragments of trilobites, Orthis, Strophomena, Rhynchonella, etc., are derived from here, though often much distorted, owing to the great crushing to which the beds have evidently been subjected. Some of the shales are somewhat white and chalky, while others are ferruginous.

Maymyo to Wetwin ("Wenwi" of map).

Maymyo is on the 42nd milepost on the cart-road to Lashio on the way to the Kunlon Ferry, while Wetwin ("Wenwi" of map) is on the 55th. In proceeding from Maymyo to Wetwin by the cart-road exposures are few, but the rock chiefly seen is the calcareous sandstone or siliceous limestone. If one goes along the railway track, beds of a greyish limestone with a distinct dip to the east are visible on the stream-bed about one mile east of Maymyo. Beyond this point, although the cuttings show the sandy limestone all along the line to Wetwin, they are found so pressed and crushed and broken that it is often difficult, if not impossible, to even make out the dip, and this state of things continues all the way to Wetwin. With the exception of a very few minute gastropods found about half-way between Maymyo and Wetwin, no other fossils were obtained from here.

Fossils.

Just north of the village of Wetwin, *i.e.*, by the 55th mile on the cart-road, the western bank of the road exposed, on being cut into a grey to yellowish toughish shale, and from this a fair collection of fossils was made, among the fossils being Pterygotus, Fenestella, bivalves, etc.

Wetwin to Kyaukkyan.

The cart-road on leaving Wetwin runs at first north by east and then a north-east course is maintained till it reaches Kyaukkyan on the 74th milepost. This interval from Wetwin to Kyaukkyan is almost a perfect blank, because of the ground being here low and level and nothing whatever being seen except bits of limestone here and there. A good deal of alluvium overspreads the country. Even the hills, as between Sikho and Thonze, present no exposure of rocks owing to the thick soil. After passing over this blank of nearly eighteen miles, it is a great relief and satisfaction to come across, at Kyaukkyan, shales which yielded plenty of fossils. A low range occurs here, running north by west and south by east, and the railway passes through a deep cutting through this range. It is a fairly long cutting, and at the western end of it is

Fossils of Kyaukkyan.

exposed a shale dipping eastwards; in the centre occurs a thick-bedded, highly crushed and brecciated siliceous limestone; while at the very eastern extremity, after a blank of 200 feet or so just beyond the central mass of grey limestone, is seen a darker grey limestone with a distinct dip to the west. Fig. 7 represents what is actually to be seen in the section along this cutting, while as to how I would read this section is represented in Fig. 8 (see Plate, Figs. 7 and 8.)

Section at Kyaukkyan.

I thus make out a synclinal fold here. The easterly dip of the shales is unmistakable, and it seems also clear to me that the central limestone mass shows at its western portion a distinct bedding parallel to, and identical with, that of the shales. The rest of the central mass of limestone looks so confused and crushed that all signs of the original bedding has disappeared, except perhaps at its very eastern border, where I think one can just make out a bed as dipping to the west. The westerly dip of the limestone in the eastern end of the cutting (*i.e.*, through the darker-grey limestone) is perfectly clear. Thus it appears to me that the limestone in the eastern end of the cutting passes under, and is thus older than, the fossiliferous shales at the western extremity of the cutting.

These fossiliferous shales are of course well exposed in the railway cutting, but they are also to be seen on the cart-road which passes close along the railway here.

Kayaukkyan to Nawnghkio and the gorge.

From Kyaukkyan the railway line as well as the cart-road run north-east by east as far as Nawnghkio, five miles from Kyaukkyan, the limestone being observed on the route to dip at a small angle to the west. From Nawnghkio the railway proceeds towards the Gokteik gorge, in an east by north direction, while the cart-road runs nearly north, crossing the gorge at a point about 2 miles (in a direct line) north-east of the town. In the neighbourhood of Nawnghkio no good sections are available, but the beds must resume their easterly dip about here, for on the western side of the gorge close by the beds are seen dipping to the east.

As one follows the railway track from Nawnghkio to the gorge the prevailing rock is found to be the light grey, siliceous limestone with occasional calcareous blue beds and some sandy shaly beds; the dip being east by south. The western slopes of the gorge at the point where they are making the railway bridge are a good deal covered with soil and calcareous tufa and no good sections are visible, but on the opposite, eastern bank, thick-bedded, siliceous limestones are well exposed, forming precipitous cliffs.

The section across the gorge at the point where they are making the railway would roughly be like what is represented in the sketch section shown in Fig. 6 (see Plate), where the rocks seen on the eastern side of the gorge are, in descending order:—

1. White calcareous sandstone, or sandy limestone (as at Yebin).
2. Sandy shale, greenish white, thin bedded, soft, weathering black, with a masonry look on the weathered surface, in places brecciated.
3. Fine-grained argillaceous shales (somewhat sandy) breaking up into small angular pieces.
4. Blank.
5. Fine-grained, white calcareous sandstone.
6. Massive bedded white to light to dark-grey siliceous limestone.

In Fig. 6, R. stands for part of the railway bridge as seen already constructed at the time of visit to the gorge, and N6 stands for the "natural" bridge, composed of calcareous tufa.

"Natural" bridges over the gorge.

There is a "natural" bridge here (one of several in this neighbourhood) over which they are taking the Railway bridge. These "natural" bridges have been formed by calcareous tufa, *i.e.*, from the re-deposition of calcium carbonate from waters containing the mineral in solution.

Section in the gorge along the cart-road.

If one proceeded, however, to cross the gorge by the cart-road from Nawnghkio, the section would appear to be somewhat different from that observed near the Railway bridge. As he descends into the gorge, he will pass over, on the western side, siliceous limestones with purer calcareous beds, light to dark grey and bluish in colour; greenish, rather hard, sandy shales, in places micaceous; sandy clays, and red shales much indurated; while on the eastern or Chaungzon side will be noticed limestones, arenaceous shales, and siliceous or sandy limestones. From the greenish sandy shales, between the 84th and 86th mileposts, on the western side of the cart-road bridge, fossils similar to those found two miles north of Maymyo were collected. On the eastern side of the gorge, at the 88½ mile (a mile and a half past the Chaungzon Inspection Bungalow), or about one mile north by west in a direct line from the cart-road bridge over the gorge, a few fossils were also obtained from a somewhat arenaceous shale. The difference in the character of the two sections—one along the cart-road and the other by the Railway bridge—is due to the fact that, while in the northern (cart-road) section across the gorge older beds are exposed in the deeper parts of the gorge, only the higher (younger) beds are to be seen along the railway track.

Thick surface soil east of the gorge.

On the eastern side of the gorge a new difficulty presents itself. Hitherto the vegetation and soil had been a drawback bad enough; but now the surface red soil, resulting from the decomposition of the rocks *in situ*, assumes such thickness and proportions and is so widespread as to baffle all attempts at getting at the solid rocks underneath. The railway cuttings near the gorge, which are in places of considerable depth, show the most irregular and curious way in which the rock (limestone) has been eaten into in the course of its decomposition from above. And this state of things prevails over a considerable distance as one proceeds north-eastwards from the gorge towards Pyoung-goung and Thibaw.

Fossiliferous shales two miles north of Gokteik village.

A mile and a half beyond the Gokteik Inspection Bungalow, that is, about 100 yards short of the 97th milepost on the cart-road, or two miles north of the Gokteik village, was discovered, on the eastern side of the cart-road, *i.e.*, between the cart-road and the railway track, which are only a few yards apart here, at the bottom of an excavation from which the soil had been extracted for making the railway road, a very fine-grained, well laminated, purely argillaceous shale, grey to bluish in colour, but occasionally carbonaceous, and splitting up well along lamination. A rather interesting group of fossils was obtained from these beds. A short distance south-east of this spot and on the eastern side of the railway line are exposed, at the foot of a hill, some white sandy limestones; these also yielded a few minute bivalves and gastropods. These two collections constitute all the fossils that could be got in the neighbourhood of Gokteik village.

Wetwin and Gokteik shales not identical.

Although physically the Wetwin shale somewhat resembles the Gokteik shale just described above, the fossil contents show that they are not the outcrops of the same beds and that the one is different from the other, the former being of an older age than the latter.

On the way to Pyoung-goung.

On the way to Pyoung-goung, with the exception of a few minute gastropods derived from some limestone near Tengwing, between the 99th and 100th mile-posts, where the beds are seen dipping at a small angle to E.25°N., nothing whatever was obtained in the way of fossils, most of the exposures being bits of limestone at the bottom of quarries dug in connection with the railway making. The hills on either side were here and there explored, but the thick soil on them defied all attempts to get at the rocks beneath.

Among the hills to the east and north-east of Pyoung-goung there are some outcrops of thick-bedded limestone dipping east by north at 10° to 15°. They yielded however no fossils.

Pyoung-goung to Lwekaw.

Fossils near Loiyang.

Fossils four miles north-east of Pyoung-goung.

Exposure three miles west of Lwekaw.

From Pyoung-goung (on the 105th mile on the cart-road) to Lwekaw (on the 116th mile) hardly any exposures are visible along the cart-road, but sections are available along the railway line. Proceeding, then, by the latter: From some limestone exposed in the railway quarries on the eastern side of the line, just south of Loiyang, a village one mile north of Pyoung-goung, some minute gastropods and sections of fossils, not recognizable, were obtained. Numerous cuttings, principally through siliceous limestones, occur along the line, all exhibiting signs of much crushing, but yielding no fossils. But at a point four miles from Pyoung-goung there is an exposure of a soft yellow shale which yielded numerous Fenestellas, Crinoid stems, a trilobite, some corals, and bivalves. This is succeeded by a blank for three miles, when again, that is, about three miles west of Lwekaw, a good section of limestone is obtained. The rock here is rather thin bedded mostly and grey in colour, some of the beds being, however, bluish. From these were extracted some ferns and bivalves. The dip here is east by north at 25°. From here to Lwekaw the section is nearly a blank, except some beds of limestone seen on the stream-bed at Lwekaw itself.

Lwekaw to Kyinsi.

From Lwekaw to Kyinsi (on the 125th mile), a distance of 9½ miles by the cart-road, exposures of limestone are occasionally met with along the cart-road, but though no success resulted so far as the finding of any fossils

Fossils at between 1 and 1½ miles west of Kyinsi.

These fossils identical with the Kyaukkyan ones.

went, that does not of course prove that these beds are not fossiliferous. The railway track, however, gave better results. The section is a blank for some miles from Lwekaw. At a point about three miles west of Kyinsi, which is situated near the mouth of the Namsim river, a fine section of argillaceous shales with limestone is exposed, but this yielded no fossils. Nearer Kyinsi, however, there are several small cuttings between 1 and 1½ miles from Kyinsi. Argillaceous grey and reddish calcareous shales with grey and blue limestones exposed here are very fossiliferous. The dip here is north-east at 45°. These fossils being similar to those of the Kyaukkyan beds, we have at Kyaukkyan and at Kyinsi outcrops of the same beds. Going on towards Kyinsi, the exposure by the cart-road bridge on the Namsim, a little above its mouth, yielded some plant-remains and corals.

Kyinsi to Thibaw.

From Kyinsi (125th mile) to Thibaw (Hsi Paw), which is on the 132nd milepost on the cart-road to Lashio, no solid rocks are visible whether one proceeds by the railway or the cart-road. There is a saline spring at Bawgyo, from which the Burmans extract, by simple evaporation, a lot of salt for purposes of sale.

Neighbourhood of Thibaw (Hsi Paw).

Thibaw itself is in a valley and gives no sections either in the town or in its immediate vicinity. The ¼-inch map, which was the only map I had with me of this neighbourhood, is also far from satisfactory, so far as the hills in the immediate neighbourhood of the town are concerned, adding thus to the difficulties of one's work. Going on to the hills to the north-west and north of the town, one finds, by the village of Honam (not on the map, but near "Babaiki" of map) exposures of limestone, which is here a pure rock, quite free from any admixture of sand, passing, traced eastwards, into an argillaceous shale, finely laminated, pale yellowish green in colour, and somewhat calcareous at first, but gradually being free from the calcareous element and giving place to a grey and greenish, purely argillaceous, shale. The limestone above the village yielded sections of bivalves, not, however, recognizable; but in the small exposures available of the shales into which the limestone is seen to pass, I did not succeed in finding any fossils. The shales are here vertical;

striking nearly north and south. On the hills north-east of this point shales are clearly visible at places. Going on again to the hills north by east of Thibaw, bits of a sandy limestone are at first passed over as if the parent rock *in situ* below were a calcareous sandstone or arenaceous limestone. Proceeding further in the same direction fragments of sandstone are seen. After a blank, a conglomerate, composed of fragments of limestone and of sandstone, is met with. The pebbles are of different dimensions, some measuring as much as 6 inches in length. Some of the constituents are well rounded, but a good many exhibit an angular outline. Proceeding further, no regular beds were seen, but fragments of sandstone were noticed on the ground. A spotted variety of the sandstone was noticeable as being very abundant—the rock being a light grey sandstone with evenly distributed fine dots of red. Beyond this point the ground became obscure.

Thibaw to Kongsa.

Crossing over to the southern bank of the river at Thibaw and proceeding along the cart-road eastwards, within half a mile of the Thibaw Inspection Bungalow (at 133⅝th mile) the ground rises by the left bank of the river, but no solid rocks are exposed until about quarter to half a mile further beyond, where a sandstone is seen. It is a hard rock, medium to coarsish-grained, yellow to brownish green, and much jointed; but as one goes on a reddish or reddish-purple variety of the rock, interbedded with thin bands of purplish shales, and in one place an impure thin calcareous band, are noticeable. The rock is, however, beautifully exposed a little further on, that is, in the railway cutting on the right bank of the river, at a point two miles due east of Thibaw. It is a reddish purple, rather fine-grained sandstone, thin to thickish bedded, with intercalated shales of the same colour, dipping E. 35° S. at 55°. In going on, by the cart-road, to Kongsa, about nine miles east of Thibaw, the reddish-purple sandstone and shale constitute the chief rocks seen, but about one mile west of the Kongsa Bungalow, a very impure limestone, evidently interbedded with the sandstone and shales, is seen.

Sandstone and shales, with impure calcareous beds.

Near Thibaw limestone seems to pass into shales and sandstone.

Thus from the examination of the ground in the neighbourhood of Thibaw it seems to me that the limestones pass into argillaceous shales, which become gradually sandy and eventually pass into the red and purple sandstones east of Thibaw. The conglomeratic band seen three miles north by east of Thibaw apparently marks only local denudation. As I had to resume my return march to Mandalay from Kongsa, my examination of the ground did not extend beyond this point.

Having now cursorily glanced over the character of the different rock-exposures one meets with as one passes along the Mandalay-Lashio cart-road or railway track from Mandalay to Thibaw, and pointed out the various localities which have yielded fossils during the season, it now becomes necessary to indicate the general structure of the ground, showing the relations of the different groups of rocks with one another and their probable age.

Rocks classified.

The rocks passed over from Tonbo on one's way to Thibaw may be arranged into the following divisions :—

(1) Tonbo beds.
(2) Zibingyi beds.
(3) Maymyo beds.
(4) Wetwin beds.
(5) Kyaukkyan beds.
(6) Gokteik beds.
(7) Thibaw beds.

Tonbo Series.

By Tonbo beds I shall indicate the sequence of the limestone beds forming the foot-hills of the Shan plateau, *i.e.*, the hills in the neighbourhood of Tonbo and Sedaw. The rock is purely a limestone in the neighbourhood of Tonbo and it is only by Sedaw that argillaceous shales begin to appear. The limestone passes gradually into shales which, from an ordinary grey or mud-coloured variety, passes into a red kind. The north-and-south valley, a little to the north-east of Sedaw, evidently resulted from the excavation of the red shales, etc., that form a syncline here, the syncline being followed eastward by an anticline whose eastern limb is now exposed about the 17th milepost, that is, the third and fourth reversing points on the railway and also between 17th and 18th mileposts on the cart-road. These red shales pass up into dark grey shales and these into limestone. In this series may thus be included all the beds as far as the base of the Zibingyi syncline. The beds near Nyaumbaw with the Crinoids, *Orthoceras*, *Echinosphærites*, etc., will thus come in in this series.

The fossils found in the Tonbo beds are corals (*Syringophora*, Strombodes?), brachiopods, lamellibranchs, gastropods (*Euomphalus*), stems and arms of Crinoids, *Echinosphærites*, *Orthoceras*, *Gomphoceras?*, etc. These have not been specifically determined yet, but they point to a lower silurian age.

Zibingyi Series.

Under the designation of Zibingyi series are included the limestones and shales forming the synclinal fold at Zibingyi. It does not seem to me of much use or profit yet to attempt to subdivide these beds into more than two divisions, namely, an upper one, containing graptolites, and a lower one with the trilobites and Styliolas. Orthoceras and Crinoid remains occur everywhere, abounding as they do also in the Tonbo beds, and so they are not of much help in a minuter classification of any of the beds here.

The Zibingyi series of beds occur in three little separate areas: one at Zibingyi itself, the second about Pyinsa and Thongdaung, and the third just north of the Thongdaung Railway Station.

The specimens of graptolites that have been collected from these localities are all of the monoprionidian order, not a single diprionidian graptolite having been found in them. Hence the presumption is that the Zibingyi series of beds are, to judge by the graptolites alone, of the upper silurian age.

Maymyo Series.

The Zibingyi beds pass up into shales and limestones with introduction of sandy elements among them. Sometimes the rock is an arenaceous limestone or calcareous sandstone; at other times it is a pure sandstone; these varieties being well seen as one passes from near Waboye to Maymyo. The hills just west of Maymyo are composed of this siliceous limestone and calcareous sandstone. About two miles north of Maymyo argillaceous shales, somewhat sandy, are exposed, and Orthis, Strophomena, Fenestella, fragments of trilobites, etc., have been found in them. Apparently the siliceous limestones, etc, seen west of Maymyo pass up into these shales and as the fossils indicate a silurian age, the Maymyo series of beds seem to belong to the upper silurian period.

The beds exposed in the deeper parts of the Gokteik gorge, as seen by the cart-road bridge, are silurian in age. But no characteristic fossils having yet been found in those exposed in the upper parts of the gorge, as seen by the Railway bridge, it is difficult to say if they are devonian or carboniferous.

Wetwin Series.

The name of Wetwin ("Wenwi" of map) series may be applied to the group of rocks in the neighbourhood of Wetwin, a fairly good collection of fossils having been yielded by them. The fossils were found in a band of toughish shale interbedded in the siliceous limestones. A band of ironstone occurs a little below the fossiliferous shales. Among the organic remains found here occur Fenestella, Hyolites?, lamellibranchs, Entomis serrato-striata?, and Pterygotus, which would seem to point to a devonian age.

If the Wetwin beds are devonian, it is not likely that the shales seen 2 miles north of Maymyo on the way to Naungkangyi are other than upper silurian. For if they were lower silurian, faulted up against the upper silurian siliceous limestones of the hills just west of Maymyo, it is difficult to explain the total and entire absence of the upper silurian Zibingyi beds between Maymyo and Wetwin.

Kyaukkyan Series.

There is a blank of 18 miles between Wetwin and Kyaukkyan in which only an occasional outcrop of limestone is seen. At Kyaukkyan, however, the shales at the western end of the railway cutting are highly fossiliferous. This series of beds—the shales with the associated limestones—at Kyaukkyan, may be termed the Kyaukkyan series.

Gokteik Series.

By the 97th mile post on the cart-road, or 2 miles north of Gokteik village, occurs a dark grey toughish shale which has yielded some rather interesting fossils. These shales with their associated beds I will designate as the Gokteik series.

Thibaw Series.

The limestones as seen in the hills north of Thibaw, pass into argillaceous shales and these apparently into the reddish-purple sandstones so well exposed on the railway cutting 2 miles east of Thibaw. No fossils have been found in them, but from their position they are younger than the Kyinsi beds. These shales and red sandstones with limestone constitute the Thibaw beds.

Now the Kyaukkyan fossils appear again between 123rd and 124th mileposts, near Kyinsi, and in the interval between these points, in two localities, namely, one at 2 miles north of Gokteik village and the other at 4 miles north-east of Pyoung-goung, fossils were discovered. As there are considerable gaps between these several points of fossiliferous exposures, the structure of the ground must be mainly dependant on, and inferred from, the nature of these fossils.

From the occurrence of a synclinal fold at Kyaukkyan, as I make it out to be, and the repetition of the Kyaukkyan beds at Kyinsi, the structure of the ground would appear to be simple, *i.e.*, a syncline followed by an anticline, as attempted to be diagrammatically represented by Figure 9 (See Plate, Figure 9) which, if true, would make the Gokteik and Pyoung-goung fossiliferous beds older than the Kyaukkyan (or Kyinsi) beds. All the fossils have not yet been specifically determined, but I understand that the Kyaukkyan fossils are regarded as devonian. As regards the Pyoung-goung fossils, there is, I believe, nothing in them to prevent their being regarded as devonian or perhaps even silurian. But this does not seem to me to be the case with the Gokteik fossils. I have not been able to identify them yet, but will try to indicate some of the characters of the most important ones here, all of these belonging to the Arthropoda. Fossil No. (1). This presents an outline broader in the cephalic end and tapering towards the tail, with the limbs, all of them apparently situated near the cephalic end, well segmented and with the minute hairs on them distinctly visible; and there is no indication of segmented limbs with hairs towards the tail, which looks flattened and fan-shaped. There is no sign of trilobation whatever in any of the specimens of this fossil, and no haired limbs at the tail end. All this would seem to me to point against its being a trilobite. The resemblance of the organism, however, to a macrurous decapod appears to me to be close. Fossil No. (2). That this also belongs to the Crustacea there seems to be no doubt. With its body slightly bent and tapering towards the tail, and with its dorsal segmented chitinous or horny-looking carapace, and segmented ventral limbs, the resemblance is so close and striking to some of the macrurous decapods that I can scarcely entertain any doubt in my mind as to its being one of them. Fossil No. (3). In this only a portion of the posterior terminal or tail end of the animal is preserved. I do not feel quite sure about it, but the resemblance leads me to regard it as belonging to Eryon, also a macrurous decapod, or to a crustacean closely allied to it. Fossil No. (4). The outline of the organism is oval, the cephalic portion presenting a conical section, with segmented slender limbs about the shoulders and about the region corresponding to the pelvis. In

Structure of the ground.

Characters of some of the fossils of the Gokteik Series.

some of the limbs the hairs can be well made out. Everything considered, it looks like the remains of an insect of the Hemiptera or Coleoptera order. Besides these, other specimens, collected also from here, appear to be fragments and portions of wings and other portions of insects.

Inference from these fossils.

Now Hemipterous insects appear in the silurian period and range up to the present day, while Coleopterous insects do not appear till the trias. So, as far as the insect remains here are concerned, they do not help us much in determining the age of the Gokteik beds. But should the other Crustacean fossils really prove to be the remains of macrurous decapods, as they appear to me to be, then, since no typical decapods appear until the trias is reached, the Gokteik beds cannot be older than trias and must be triassic or younger. Should the Gokteik beds be then mesozoic, they must be supposed to have been faulted in against and between the devonians at Kyaukkyan and Kyinsi, should the beds at Kyaukkyan or Kyinsi be devonian.

Should the above be the correct interpretation of the structure of the ground, then the Thibaw beds (the limestones, shales and the reddish-purple sandstones [1]), being higher in the sequence than the Kyinsi beds, must be looked upon as upper palæozoic.

Another view as to the age of the beds.

The fossils collected this season have not yet been examined closely or determined specifically, and until this is done the above explanation as to the structure of the ground must be regarded as provisional. Such being the case, it may perhaps be permissible to indicate here any other view or views that may have been entertained as to the possible age of the beds and structure of the country traversed this season. As already indicated, I took it that there was a sharp syncline at Kyaukkyan, followed by an anticline, the eastern limb of which was now exposed at Kyinsi; and that all the beds—the Gokteik series—between these points, lying under this anticlinal fold, were thus older than the Kyaukkyan or Kyinsi beds. Should the Gokteik beds be triassic or younger, the Kyaukkyan beds would necessarily be younger still, that is, middle or upper mesozoic; [2] and in that case the shales and red sandstones of the neighbourhood of Thibaw, being younger than the Kyinsi beds, would be cretaceous or even tertiary. I might state here that the conglomerate and red sandstone I have described as occurring near Thibaw present such close resemblance to the same rocks found by Mr. Middlemiss this season in the southern Shan States, not very far from our own ground, that in all probability whatever the age of the one is also the age of the other, and I believe Mr. Middlemiss is inclined to look upon them as of tertiary age.

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[1] These are the red sandstones of undetermined age of Dr. Noetling. Rec. G. S. I., Vol. XXIV, pt. 2, pp. 103 and 104.

[2] I may add here that in the Kyaukkyan collection there are some fossils which are so remarkably like some mesozoic ones that should they prove to be what they look like, they would carry the age of these beds into the upper mesozoic, namely, cretaceous, period.

Economic Geology—Among the economic products come across during the field season just ended may be mentioned :—

(1) Metallic ores.
(2) Limestones.

(*1*) *Metallic Ores.*—Ferruginous ore is the only metallic ore I met with in my traverse from Mandalay to Thibaw. The localities where I saw this are—

(i) Between the third and fourth furlong posts past the 39th mile on the Mandalay-Lashio cart-road, or 2½ miles beyond the village of Singaung, or about three miles south-west of Maymyo a highly ferruginous rock is seen along the roadside. It looks rich in iron. The rock can be traced for 30 to 40 yards along the road, but want of exposures makes it difficult to estimate its probable extent.

(ii) About half a mile north of a little village called Twinnge, which lies a little over two miles due north of Thongdaung Railway Station on the Mandalay-Kunlon Railway, is a hill whose top, *i.e.*, so much of it as is exposed, shows masses of a very rich iron ore, probably hæmatite with magnetite. The surfaces of the masses of the ore are seen covered with minute magnetic, needlelike rods which move about as one passes one's hammer over them. There is no doubt that it is a very rich stuff, but the ground around and about the hills must be a little more cleared before one could estimate with any degree of certainty as to the quantity of the ore here, which is apparently large.

(iii) Some ferruginous rock was seen by the Wetwin village, about the 55th milepost on the cart-road, apparently bedded and underlying the Wetwin fossiliferous shale. I saw this rock again about a mile and a half east by north of Wetwin. So this is in all likelihood a ferruginous band of ironstone occurring associated with the shales here.

(2) *Limestone.*—This rock, it is needless to say, occurs here extensively:—

(*i*) It is being used for road metal.
(*ii*) It can be, and is being, utilized for making lime.
(*iii*) When selected it would also, no doubt, make good building stones.

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Report *on a* Geological Reconnaissance *in* parts *of the* Southern Shan States *and* Karenni, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

CONTENTS.

		PAGE.
SECTION	I.—GENERAL REMARKS	123
„	II.—PHYSICAL GEOLOGY AND GENERAL TECTONIC FEATURES OF THE AREA.	126
„	III.—STRATIGRAPHICAL AND COMPOSITIONAL ZONES	127
	(*1*) *Gneissic and Metamorphic Zone*	128
	(*2*) *Great Limestone Zone*	130
	(*3*) *Purple Sandstone Zone*	143
	(*4*) *Sub-recent or Upper Siwalik Conglomerates, Sands, Loams and Clays.*	147
	IV.—ECONOMIC GEOLOGY	148
	(*1*) *Coal and Lignite*	148
	(*2*) *Copper*	150
	(*3*) *Gold*	151
	(*4*) *Lead*	151
	(*5*) *Pyrites*	152
	(*6*) *Saltpetre*	152
	(*7*) *Tin*	152
	(*8*) *Tourmaline (green)*	152

I.—GENERAL REMARKS.

Objects and method of tour.

The notes which follow were made during a short season's tour (from early in December 1899 to the end of March 1900), and do not pretend to be anything more than rough geological jottings. My object was to cover as much ground as I could in the allotted time, and to ascertain the possibilities of the country, rather than to make even a sketch-survey. No attempt at detailed mapping was made. My marches generally were either daily or with one day's halt—but rarely more than one. They were also made along definite lines across the country, the shortest routes in fact available.

Present difficulties in the way of a detailed survey.

In most parts visited a more elaborate survey would, for the present, have been out of place. For, firstly, the country, which has only been indirectly administered by our Government for thirteen years, is not yet one in which the searcher after scientific facts can feel entirely at home. He is hardly allowed to travel by himself and as he lists. In some cases he must have a police-guard or even a military escort. He is still liable to be treated as a guest by the people of the states, and his actions consequently hampered in a multitude of easily-imagined ways by all that is implied by the word guest. With all laudable intentions the native state officials seek to make much of him—to meet him with processions, to call upon him with gifts, in and out of season. Secondly, the physical conditions of the country through which I passed are against detailed work, at least at present; whilst over much of the area, unless useful minerals are found, I am of opinion that any approach to real geological mapping cannot advantageously be done. These physical conditions briefly stated are: (1) heavy jungle and sparseness of footpaths, except along the higher and flatter plateaux, which necessitate the geologist keeping to arbitrary beaten tracks: (2) scarcity of villages and supplies with the exception of the plateaux noted above; and which again necessitates a pre-arranged plan of tour, and one that must be kept to at least generally, in spite of vagaries of the rocks (this is notably the case in Karenni): (3) the nature of the dominant rock formation, which being a massive limestone presents all imaginable difficulties to the stratigraphist, chief among which are absence of distinct bedding, irregular weathering, chaos arising from underground drainage, local subsidences and the rareness of erosion channels exposing anything but tumbled blocks; absence of striking petrological horizons that would help out the last difficulty if present by furnishing a key to their unravellment; and last, but not least, the absence of railway-cuttings and road-cuttings, except in the solitary case of the Government cart-road from Thazi to Möng Pawn. This last is really of more consequence than it seems, especially when it is considered in connection with the nature of the rock; for the tendency on every hill-side is for the thin-bedded shaly layers (which are the most likely to yield recognizable fossils) to be completely obscured by the chaotic tumbled blocks and the thick surface clay into which they weather.

In the third place, though much of the southern Shan States has been topographically mapped on the 1 inch = 1 mile scale, some of it, and especially Karenni, has to be content with nothing more advanced than the ¼ inch = 1 mile reconnaissance sheets, which in hilly forest-covered country are almost useless for geological purposes. In the fourth place, beyond the narrow zone of crystalline igneous and metamorphic rocks fronting the Irrawaddy plain, there are no igneous rocks whatever in the area visited by me, neither bosses, dykes, nor contemporaneous volcanic flows. Thus all interest centering in pure petrological work has no scope in this part of Burma.

In spite of the above rather formidable array of difficulties in the way of an elaborate geological survey, as understood generally, it is hoped that the results I have obtained, sketchy as they are, will at least lift the veil of ignorance under which its geology has hitherto lain; and, taken together with Messrs. La Touche and Datta's recent work further north, furnish a rough guide to the general geology of part of this eastern frontier of the empire.

Obligations.

Owing, as already stated, to the political disabilities which obtain in these frontier parts of our empire, my traverses, except along the bungalow-studded Government cart-road, were somewhat of the nature of personally conducted tours, made under the auspices of one or other of the civil officers in charge of the native states. For the arranging of these I have to express my great obligation to Mr. A. H. Hildebrand, C.I.E., Superintendent and Political Officer of the southern Shan

States, who (at rather short notice) gave me most efficient help. To Mr. C. E. Browne, Extra Assistant Commissioner of the Myelat, I am indebted for his taking charge of me during the early part of my tour, and for his personal interest in and carefully collected data about, the mineral wealth of the states under his care; and to Mr. W. G. Wooster, Assistant Political Officer of Karenni, who took me over from Mr. Browne and piloted me pleasantly and successfully through the Karenni country, and saw me across the Toungoo border. To the above especially, and to several other civil officers resident in Taunggyi in a less degree, I have to tend my best thanks for many courtesies and kindnesses received in this, to me, rather strange land.

Previous work in this area.

Although the greater part of the country traversed by me was geologically unknown, a few localities had been rapidly visited by my late colleague, Mr. E. J. Jones, A.R.S.M., in 1887, for the purpose of investigating the coal, lignite and other minerals there found. His results are given in Records, Geological Survey of India, Vol. XX, Part 4, 1887, pages 177-194. His operations were conducted under conditions far less favourable than mine, and at a time when the country was only just recovering from anarchy and from harassment by dacoit bands. Furthermore, the only map he possessed was on the scale of $\frac{1}{16}$ inch = 1 mile. Hence he made no attempt to delineate the formations or to generalize his geological data, and confined his notes strictly to the mineral occurrences which he investigated. Dr. F. Noetling in more recent years paid some similar brief visits to the country immediately to the north of my area, and has published his notes in Records, Geological Survey of India, Vol XXIV, Part 2, page 103. Mr. La Touche, who contemporaneously with me has now been visiting the northern Shan States, has added to and amplified the above geological data. He is reporting on his work so that I need not recapitulate them here. In the Manual of the Geology of India, 2nd edition, page 142, a brief allusion is made to the probable continuation north along the Salween river of the Moulmein carboniferous limestone.

So far as I know, the above embody all the co-ordinated information that has been gathered by qualified geologists in this area.

II.—PHYSICAL GEOLOGY AND GENERAL TECTONIC FEATURES OF THE AREA.

Before describing the traverses I have made through the area, it will be well to state shortly and comprehensively for the whole of that area such salient facts as to the physical geology and the general style of rock architecture, and tectonic geology as, notwithstanding the poor sections and absence of striking stratigraphical horizons, have nevertheless made themselves sufficiently evident to me.

A great elevated compound zone of formation.

To begin with, the whole earth's crust of this part is a great elevated compound zone of disturbed rocks comprising three or four minor stratigraphical or compositional zones. It consequently is a region of special upheaval resembling the Himalayas, and embraces hill-ranges of considerable height; all, however, in this latitude well below snow level and the influence of ice in any form.

Hill-ranges and valleys.

The hill-ranges run mainly in directions roughly north and south, and are divided by eroded longitudinal valleys of, as a rule, no very great steepness except in the case of the Salween and Pawn rivers. The minor parallel streams are frequently very irregular and indiscriminate in their courses, complicated as they are by sudden underground disappearances, and by sharp cross branches which dash through gorges at right angles to the ridges and may then turn either north or south.

Plateau aspect.

Except for the larger and deeper valleys just mentioned the greater part of the area I have crossed, besides being characterized by parallel hill-ranges and valleys, is as a whole of an elevated plateau aspect. Wherever great masses of the limestone formation are in force they build scarps and plateaux in numerous array—a result which may in many cases be seen to be due to a roughly rolling dip of the great thick-bedded formation, but in other cases is helped out by sub-recent or uppermost tertiary deposits infilling what were once shallow valleys between alternate scarps.

Amount of folding and compression of the area uncertain.

But with all this I have not been able to gauge the approximate compression, folding, and faulting that have actually taken place. For it is impossible without distinct bedding and marked fossil, petrological, or colour horizons to distinguish a series of superposed and closely packed overfolds, sigmaflexures and lying anticlinals and synclinals from a gently undulating series of normal folds.

That, however, the plateaux are not altogether simple, normal undulations of a vertically elevated block of strata, seems indirectly certain from a variety of considerations. In the first place there are the remarkably straight boundaries between different formations; there is also the tendency to a universally oriented strike whenever it can be observed, and, as a corollary to the above, an arrangement of the formations in straight bands and a (broadly speaking) settled sequence of them from west to east wherever a line of section is taken.

Hence, this Southern Shan plateau differs somewhat from a typical table-land, and possesses some of the characteristics of mountain areas like the Himalayas, which have suffered distinct sets of lateral compressions at different times with crumpling and possibly overthrust accompanying such. But along with this qualitative statement it is quite impossible at present to write down how much, and to what extent, these earth movements have progressed.

III.—STRATIGRAPHICAL AND COMPOSITIONAL ZONES.

As already stated, the geological fabric of these hills may be split up into a number of steadily striking zones or bands, of distinctive character as regards stratigraphy and composition. They lie parallel to one another, and they generally outcrop in a definite order from west to east. Although the imperfections of the sections give no clue to the exact style and amount of folding, and by consequence no evidence as to the relative positions of these distinctive bands in the geological record, there are other considerations which enable us to place them provisionally in the following order of time sequence :—

Order of Zones.

(1) Gneissic and Metamorphic Zone.
(2) Great Limestone Zone.
(3) Purple Sandstone Zone.
(4) Sub-recent conglomerates, sands, and loams.

(*i*) *Gneissic and Metamorphic Zone.*

Archæan, intrusive, and metamorphic facies.

I am compelled to put this as the oldest of the sequence because of its archæan facies in part. In many ways it presents an appearance of great age, for it contains true gneisses with intrusive plutonic veins, and also much metamorphosed, foliated, cleaved, and cataclastic rocks.

Area of zone confined to west side of plateau.

So far as I have observed, it is confined entirely to the western edge of the described area, and, though not politically included with the southern Shan States, it forms topographically the western front of the Shan States plateau.

Surface features.

This western edge rises sharply from the alluvium-covered plains which form part of the Meiktila, Yamethin, and Toungoo Districts and along which, in full view of the gneissic zone, runs the railway from Rangoon northwards. As seen from near Thazi railway station, the near hill-sides, spurs and ravines of this elevated zone give evidence of free sculpturing at the hand of time. Their towering, sharp-edged ridges, with wide and deep gorges and flowing slopes between, show up remarkably like much of the older zones of the Lower Himalayas. Degradation is evidently accomplishing its work, and the thin, acute-angled, irregular, and vermiform summit ridges are being scored and fretted away into all those shapes so characteristic of a relatively old land area—a condition only antecedent to complete extinction.

Nature of western edge of Zone.

What is the structural relation that this zone bears to the alluvium-covered pliocene and miocene plain at its foot? Without any younger foot-hills separating the two, the straight unwavering western margin of the zone probably indicates a north—south fault. According as we attribute great intensity or not to the crumpling forces which upheaved the plateau, so must we regard this fault as a fold-fault or a simple upthrow fault. In any case it is likely that it was not a sudden disruption of tertiary age, but a line of more or less continuous movement that went on for long ages during the geological history of this part of Burma.

Width of the zone.

This gneissic and metamorphic zone is of narrow dimensions compared with the great expanse of rolling plateau further east. In the cross-section from Hlaingdet to Pyinnyaung it is about twelve miles, the first four of which are gneissic.

Petrography of the zone.

The gneissic rocks, as seen in the road cuttings about seven miles from Hlaingdet, and as found in fragments here and there on the hill-slopes and talus fans, are not unlike many of the mixed gneisses of Salem and Coimbatore in the Madras Presidency. They are well foliated, micaceous, and hornblendic gneisses. Intrusive among them are veins of pink syenite, white pegmatitic granite and fine grey micro-granite containing biotite and muscovite. These veins are non-foliated, and have been intruded across the foliation of the gneisses. No other good exposures of these rocks are seen on the road.

At the 18th milestone from Hlaingdet where the cart-road from the valley begins to wind among the hills towards Yenmabin there set in sub-metamorphic quartzites and slates. All are much smashed by earth crushings which have splintered them or split them up into platy layers. In this respect these rocks have a remarkable Himalayan facies. Near Yenmabin a fine-grained gneiss occurs and some pale coloured quartz felsites or micro-granites. East of Yenmabin the white quartzites and slaty rocks are less metamorphosed, and plainly indicate their sedimentary origin. Interbedded with them are occasional very thin bands of dark blue-grey limestone a foot or two wide. All are very much smashed. Further north-east towards Pyinnyaung greenish grey dark quartzites and black slaty sub-schistose rocks continue—all much fractured—and there are repetitions of all the rocks from Yenmabin over again. Near Yebokson there is a green and white mottled gneiss.

East of Toungoo a section across this same zone from west to east is much more unsatisfactory from the fact that there are no road-cuttings and the surface exposures are extremely rare. There are evidences in the stream-beds, however, showing that gneissic rocks, quartz-schists, and other metamorphic strata are there found. A large development of a very coarse unfoliated porphyritic granite is seen to the west of Leiktho. It weathers into gigantic rounded boulders, destitute of foliation or banding and contains hornblende and black mica. The eastern edge of this zone cannot be very definitely placed, but it must come somewhere near the longitude of Yado.

(2) *Great Limestone Zone.*

The most characteristic formation in the southern Shan States.

In a very wide sense this zone may be considered as the only other one existing. It is in fact, *the* characteristic zone of the Shan plateau proper. Nevertheless it is partially interrupted along certain lines by two other distinct minor stratigraphical zones presently to be described. At one time during the progress of my work I had hoped to further divide the great limestone zone into sub-zones of separate geological age and of slightly different composition. Further work south of the Government cart-road has, however, shown me that even if any differences might be made on palæontological or petrological grounds (as to which no positive evidence is yet forthcoming) the rocks could not certainly be traced north and south in recognizable bands in the same definite order that I consider necessary if they are to be judged of any value as structure zones that imply anything vital regarding the evolution of the mountain mass.

Surface features.

Every traveller and dweller in the Shan States must be aware of the characteristic features of this great calcareous zone. Though thrown into ridges and minor mountain chains, it has a general elevation that makes it enjoy a pleasant climate for several months of the year. The sun during the dry months may be hot by day, and rise and set over the billowy tableland with a fervidness unknown in less arid parts, but the nights are cold, and frost in December and January is quite a common thing. It supports a hardy population of various hill races, very different from the low-country Burman, and all speaking different tongues. It might, and probably in time will, if judiciously fostered, grow crops of cereals, vegetables, and fruits to supply Lower Burma markets, when the communications with the plains are improved and further extended. Its forests, in favoured places in the greater river-ways, are well known already for the teak and other minor forest produce that they yield.

In its essentials, and not considering the younger minor zones that are inlaid with it, it is a rugged, rocky country. The dark grey limestone frequently weathers almost black into sharp-edged honeycombed masses, into pinnacled crags and weather-beaten towers and walls: into deep basins and swallow-holes (often as regular and circular in outline as a gigantic amphitheatre, but sometimes funnel-shaped): into strange valley systems without connection one with the other, and that often end mysteriously either as underground passages down which streams precipitate themselves and become lost, or as marshes and lakes where evaporation helped out no doubt by subterranean percolation causes a disappearance of the waters: into innumerable caves and passages beneath the ground, some now high and dry from the waters that caused them and which are locally mined for the nitrates that have accumulated upon the floors from the decomposition of cave animal deposits, others used as show places and temples; others again unknown to fame and rich in their virgin beauty of stalactitic growths.

In other words the surface of this great zone has that configuration which is everywhere characteristic of massive limestone, grim aspects which in other countries would mark out the arch-enemy of mankind as its far-back land owner, and aspects which by some inscrutable wrong-headedness in lightly-thinking people are often attributed to volcanic agencies.

Except, however, in the upland valleys and the deep gorges, the sponge-like absorption that it exercises on the rainfall carries off nearly all the surface waters; so that, at least in the dry months, the ridges and slopes are generally devoid of rippling brooks and streams. What becomes of all the aerial moisture discharged on it? Perhaps in some cases a great deal is led away by underground river systems that lower down emerge into the larger and deeper river gorges. Some such underground connection is popularly supposed to exist between the Balu Chaung or Loikaw river and the Pawn. But, in the majority of cases, I believe the great network of hidden streams and torrents that run their underground courses never again emerge to the light of day, but continue ever downward till their watery burden reaching the lower heated layers of the earth's crust becomes absorbed in the aqueo-igneous fusion of deep-seated earth magmas.

In all these respects this great limestone zone presents a striking contrast to the gneissic and metamorphic zone; and nowhere is this better exemplified than on either side of the Toungoo-Karenni border. To the east roads and halting-places are restricted by the limited supply of drinking-water for man and animals, whilst still further to the east, even the great Salween and Pawn valleys, except for the immediate edge of the rapidly flowing flood, are in the dry months over large areas destitute of water and of green vegetation. Nothing is so forbidding to the traveller as the steeply graded slopes black with the ashes and charred remains of the ever-prevalent forest fires and the stems of the stunted forest growth that rise above him on either hand. Not a bird in the leafless trees, not a grub in the ash-strewn land, and not a fish in the river! The skeleton forest is not more silent and gloomy than the limpid depths of the river are tenantless. But to the west of Yado the metamorphic zone is well supplied with the life-giving liquid, rippling streams and moderate rivers are everywhere found. It possesses a thick carpet of surface soil densely covered with dark evergreen forests and alive with bird, beast, and insect at all times of the year.

Of course these statements must not be accepted as universal and sweeping in application. Among the great limestone plateaux may be found many fertile valleys; because, perchance, they run along one or other of the inlaid zones of younger formations; or because they possess an abundant supply of water kept by a lining of recent alluvium from escaping away through rifts in the valley bottoms; or because of some interbanded shaly layer associated with the limestone (a not uncommon occurrence). The general truth, however, remains as stated; and I believe that as time goes on the contrast will be more and more evident, until at last many tracts of the great gaunt plateau of the Shan Hills, having lost their surface soil and younger valley deposits by further denudation, will become mere dried-up porous transmitters of their rainfall to subterranean depths, whilst the lower plainward zone will become more and more verdant and richer in tropical forest.

But this is in the far distant future viewed through geological spectacles. From a human point of view it will be a long, long time before the plateau even partially suffers such a death as this; and the end may for all practical purposes be kept at a distance by conserving the present forests, increasing the rainfall, economizing the water-supply, and leading it by irrigation canals over as large an area as possible.

Petrography: Section along the Government cart-road.

Owing to the very fair set of artificial sections exposed along the cuttings in the Government cart-road from Pyinnyaung to Möng Pawn, which I had the good fortune to see before time had sloped them back or covered them with vegetation, this line of section and its continuation further east along a good bridle-road from Möng Pawn to Nongsewik is the best exponent of the structure and lithology of the formations composing it. I shall, therefore, first illustrate the petrography of the limestone zone by describing that section. In the description certain tentative groupings of the strata will come out, but as they were not elsewhere recognizable in a similar cross-section further to the south in Karenni, where no artificial cuttings were present to help, I have not coloured them separately on the map, save that the bands containing fossils have been added in a deeper tint of the same colour.

Pyinnyaung limestone.

Beginning at the first massive limestone that appears most westerly in the section, we find a little east of Pyinnyaung a set of towering crags forming a long ridge densely covered with forest and lifted high above the surrounding country. This band of limestone is isolated from other bands to the eastward by other rocks afterwards to be described. Whether it is of a different age to those limestones or not cannot be certainly stated. The band runs a perfectly straight course north and south. Through it in a narrow gloomy defile dashes the Pyinnyaung river by a cross rift, exposing the rock on both sides. The rock is dark and light blue-grey, massive, compact, and but slightly brecciated with recementation by calcite veins. One can see no definite bedding in it and no regular variety in its composition. Only by the absence of any apparent V-ing of the western outcrop across the gorge can one judge that its dip is at least very high. The ridge possesses very steep rugged slopes littered with titanic blocks, all emphasizing its very massive character. After many experiences in the Himalayas I would compare it with any one of the massive limestones or dolomites so common in the outer Himalayan belt. *e.g.*, the Naini Tal, Krol, and the Trias of Hazara. The gorge is about one mile long through the limestone. How much of this is direct ascent or descent in the obscure stratification, or how much folding has taken place it is impossible to say. A search for fossils was unrewarded, though much of the rock might well have been fossiliferous, judging by its compact non-crystalline state.

The same band can be seen stretching away north and south for many miles. I did not trace it or cross it again, but obtained a near view of the southern continuation of it west of Kindaung, by a traverse from Kalaw.

But it is not until having ascended to and passed Kalaw on the cart-road that one finds oneself really among the great limestone plateau. From there onwards limestone is never entirely absent from the section, the whole way across as far as I explored, namely, to Nongsewik.

Thamakan limestone.

The first recognisable unit in this great spread of calcareous formation begins about 10 miles west-south-west of Thamakan, and extends under the Thamakan plain to the west side of the Heho valley. It may be called for convenience the Thamakan limestone. It is of a rather pale neutral-grey colour, massive in places, but also thin-bedded and marly and shaly in places. Occasionally it is sandy. It bears a great resemblance to the grey limestone of Hazara, which underlies the recognisable and concretionary nummulitic limestone. From its interbandings with the thin grey shales and marls and its appearance of no great metamorphism I went about confidently expecting to get fossils at every step. Nevertheless none were found. I hammered every inch of the exposures in the cuttings during two journeys forward and backward across it but all to no purpose. The undulating surface of the plain and the low hills fringing it west and east show here a scarp and there a low dip-slope, apparently all of them fairly gentle as if a billowy broadly extended synclinal was the form the rocks here took. In the low hills west and north-west of Thamakan shales and marly beds are very prominent, and flowing moulded slopes the rule. To the east the descent into the Heho valley is very plainly a scarp with gentle dips to the west of not more than 30°, and the prevalent rock here is limestone with but few shales. The flatter plain in between, though often exposing the limestone to view, is generally occupied with newer nearly horizontal strata to be afterwards described. This plain at about 4,000 feet is generally dry and arid and bare of forest save a few bamboo clumps round about the monasteries.

Heho limestone.

Continuing the road section eastwards we first cross the flat alluvial stretch of the Heho plain, and a ½ mile east of Heho village enter upon the next member of the great limestone zone, which from certain peculiarities may be distinctively called the Heho limestone. In colour it is rather darker than the Thamakan limestone, of a blue-grey tint within, but weathering greenish-grey to a considerable depth. It is as a whole rather inclined to be well bedded, as can be seen in the road sections, is sometimes semi-concretionary and but very seldom brecciated to any extent. It is interbanded with pale shaly and marly layers. A noticeable structure in the limestone is that it possesses thin interbandings of ferruginous layers ¼ inch wide which stand out from the greenish grey limestone in marked ragged relief. In some cases as near Heho these ferruginous layers may be seen to consist of compacted shelly layers. There is just enough evidence to show that some form of molluscan life had there been present, but no more. None of the shells could be isolated or identified even genetically.

Good exposures of this limestone are found from Heho down the rather steep ghât to the Sinhe plain, which is the northern continuation of the Fort Stedman lake valley. The dips are at first to the east at rather low angles, after which there is a rolling or contorted dip either way.

Taunggyi-Hopong-Htam Sang limestone (permian in part).

The flat or gently rolling plain about Sinhe makes the next gap in our road section, which begins again with the ascent to Taunggyi. From here onwards to the Pawn river is a diversified mass of hill and flat upland plain showing great variety of limestone and associated thinner bedded shales and a few sandy limestones. This lot is grouped together here not because they are all alike, but because I cannot devise any rational separation of them. They may be entirely distinct in age from the 3 groups already described or they may contain them all, but altered beyond recognition by subsequent cataclastic action—for this is a striking feature of a great many of these minor rock bands that they have been so crushed, brecciated and recemented again that for all intents and purposes a new rock has arisen. In such layers of course no fossils have been preserved, but as we shall see presently the more eastern part of this group abounds in favoured places with remains of organisms of middle productus limestone (permian) age, which for some unexplained reason have here been able to declare themselves.

The ascent to Taunggyi is a zigzag up a scarp, the counterpart of the descent from Heho, except that it is considerably higher, especially if the summit of the wall-like crag dominating Taunggyi be taken in. The latter is as it were a second-storey planted on and a little back and east of the first line of crags and with the new settlement of Taunggyi occupying a gentle hollow between. Taunggy at a height of 4,675 feet is the head-quarters of the Government of the southern Shan States, a pleasant nucleus of a hill-station now, but given a railway communication with Burma proper, it would be capable of rapid development. There is water in abundance, a fertile soil that can produce—well almost anything that the gardener wills. The Government garden now in full swing is an earnest of what it can do, and I have memories (hardly perhaps fitting to enlarge upon here) of strawberries and potatoes obtained therefrom that will never fade.

The climb by the road up the lower scarp is a revelation of what a rock can suffer under earth stresses. Taunggyi, "the big hill," and all the other great heights between it and the Pawn river were hove up to their present level at no small cost to the foundations thereof. Almost every mile of the way is a record of brecciated, crushed and churned rock stuff that has however mostly set again into a kind of angular concrete. Some of it is white, some pinkish and some grey and sandy in texture, while some few bands intercalated between a cushion of shales, and which have alone escaped the general crushing, look as though a prolonged search in them might yield fossils. My brief search was however fruitless The crags forming the scarp at the base of the hill have a general dip of 30° east. Those at the summit building the pagoda-topped hill seem to have a general horizontality, but undulating. The general horizontality continues eastwards to Mania Sut and Maik Taung. Near Pa Leng and south-west of Hopông the north—south ridges have their strata very definitely dipping east-north-east at a low angle; and the topmost beds of these hills are very massive grey limestone. All these slopes down to Hopông are, in fact, dip-slopes, gradually lowering in angle and passing under the flat or gently flowing valley of Hopông.

Continuing the section again, still ever eastwards, beyond Hopông we find the limestones, still grey in colour, recovering and soon dipping at very low angles in the opposite direction, namely west. In other words, we have crossed a flat synclinal fold. As far as the 18th milestone from Taunggyi the gentle westerly dip continues in rather crushed sandy, white limestone, also grey and banded with pink. The exposures are not continuous the whole way, but are only found here and there in isolated lines of crags with flat terrace-like valleys between. Beyond the 18th milestone we get among larger craggy ridges which also become massed together. The road ascends more steeply and zigzags round many rocky spurs up to the pass at the 21st milestone. As far as the 20th mile things are obscure, the dip is irregular and high, the limestone crushed and powdery. From 20 to 21, however, comes a change. There are steep dips to the west in somewhat concretionary limestone with cherty lumps and blotches of crystalline calcite. Then follow dips to the east at 30 to 40 degrees in grey shales and interbedded concretionary limestone and marls.

Fossils.

In these rocks, between 20-5 and 20-6, I first found fossils (localities 1 and 2). They made their appearance on weathered surfaces in the form of corals, crinoid stems, and brachiopoda (chiefly *Athyris sp.*) They were not very remarkable in numbers or preservation, and they were mostly impossible of extraction, but at last real fossils were in evidence. Two points about the fossiliferous zones are worthy of note: (1) They are generally thinner banded, semi-concretionary limestones in the vicinity of shales; or (2) shaly and marly layers. To work the former it is necessary to wrench away or chip off a surface layer of the hard limestone. As to the latter, the best method of search is to wander along the sloped cutting in its freshly weathered state, when a good collection (of brachiopoda chiefly) may be picked out with the fingers from the crumbling loosened surface.

At the 21st milestone the road begins to descend regularly towards Htam Săng. We cross a little pass and get on the other side of the ridge. We now have before us a course of dark grey fissile shales dipping at 30 to 40 degrees to the east with one or two thin quartzitic and somewhat calcareous layers. These shales weather a pale buff or khaki colour. I could find no definite fossils, only some somewhat peculiar vermicular markings (locality 3).

Past milestone 22 with an intervening bit of covered ground, the road still descends a similar section with a few limestone bands, till near 23 miles 5 furlongs when we are rewarded by a fine section, 35 yards wide, in thin-bedded, concretionary-tabular bryozoan limestones with the usual interbedded marly and shaly layers, all packed with fossils, bryozoa, corals and brachiopoda (locality 3 *a*). The dip is as before. So far though no very characteristic and well-preserved specimens have been obtained, they suggest a middle productus limestone age.

On again past the 24th milestone, through more shales and calcareous layers till milestone 24, when for half a mile the rocks exposed are alternations of shales, marls, and concretionary-tabular limestone containing a fair abundance of corals, bryozoa, and brachiopoda (locality 4), the latter being again found in crops on the rain-loosened surface of the weathered shales as at locality 2. Among them appear several species of *Athyris cf. roysii* and *Spirigerella cf. derbyi* together with a quantity of *Chonetes grandicosta* and a few specimens of *Spiriferina cristata*, all of which are characteristic of the middle productus limestone of the Salt Range.

As we near the 25th milestone the limestone asserts itself again more massively, mostly in white, grey, and pinkish layers, very much crushed, brecciated, and probably much folded and faulted, though how much one cannot say. No fossils. Then we pass the bungalow at Htam Sāng and get down to the river-bed at 25 miles 4 furlongs. Just here is a natural bridge or covering in of the stream-bed, a limestone bridge, left like a snow bridge spanning the chasm. In the neighbourhood are said to be many caves. The road now ascends again following the river and climbing high above it to 26-3. It cuts through more of the crushed and crumbling white and sometimes pinkish limestone, in which only a vague general stratification apart from the shear planes can be recognized. It becomes dazzlingly white among the higher beds. Beyond 26-3 there is a short space without exposures, and at 26-4 appears concretionary-tabular grey limestone in thin bands among black shaly layers. This is fossil locality No. 5. For about 10 feet in the middle it is rich in fossils in the shaly or marly layers. Particularly noticeable among the fossils are large and small specimens of *Spirifer musakhelensis*, one specimen of *Productus cf. indicus* and of *Spiriferina cristata*, large numbers of *Chonetes sp.*, among which are *ch. grandicosta* and *ch. dichotoma*. All these are eminently characteristic of the middle productus limestone.

All the above may be extracted from the rock in the cutting, or picked up on the talus slopes on and below the roadway. Above and below the richer 10 feet there are 50 to 60 feet of less rich layers containing principally crinoids, corals, and bryozoa.

Up to and beyond 26-5 there next come some dark grey, splintery, much crushed shales, in which no fossils were found. Apparently a fault then intervenes, and what appears to be the last series over again from the stream is repeated, but the amount of the crushed grey and white limestones is not so great. Among it occurs a purple band of shaly limestone. The concretionary grey limestone with interbanded shales is marked by a number of chert nodules and an absence here of fossils.

The strike of the whole of this series is about north-west to south-east and the dip north-east. Beyond milestone 26-7 the road turns more easterly and curves round a hill-spur passing for a long distance through splintery shales, which as a whole seem unfossiliferous. They are generally drab, but sometimes dark grey, and they weather paler colours. They are sub-concretionary and soft. The only fossils I found in them were an ill-preserved cast of portion of a nautilus between miles 29 and 30 (locality 5*a*), some indistinct white vermicular markings just east of 30th milestone (locality 5*b*), and an impression of part of a trilobite, a gastropod, and more vermicular markings at 30-2 (locality 5*c*). It is impossible to say regarding these shales whether they are a series separate to and older than the middle productus limestone series or not. The fossil evidence is too imperfect. These shales, interrupted locally by some of the red sandstones of zone 3 and soft pale sands and loams of zone 4 continue along the road, which keeps at a low level, constantly descending, until Mōng Pawn is nearly reached, when close to the bridgeworks over the Pawn river there comes in, as if suddenly by a fault, some well-bedded concretionary tabular limestones and shales forming a low cliff running about north to south and edging the Pawn river. The interbanded shales contain many brachiopoda chiefly *Orthis indica* (locality 6). But although nothing but shales were met along the road up to this point from milestone 27, the cliffs above towards the south showed signs of the presence of the massive limestone at several points, doubtless repeated by folds and faults. Dr. F. Noetling, who has kindly helped me with my fossils, thinks that the whole of the fossiliferous series above, with the exception of those of localities 3, 5*a*, 5*b*, and 5*c*, are undoubtedly of one age and certainly belong to the middle productus limestone of the Salt Range (permian of Europe).

The wide valley of the Pawn river now makes a gap in the section, which is also complicated by the sub-recent valley deposits of zone 4. To the east of this valley the section takes us by a bridle-road up and over a lofty range, the Loi Sampu, about 5,000 feet.

For the first-half of the ascent grey, sometimes concretionary, shales, which sometimes become sandy and of a dazzlingly white or pale pink colour, dip steadily at moderate angles (about 30°) to the west or east.

Loi Sampu limestone.

There is, then, a rather sudden change and shales and interbanded limestones, the latter containing layers of compacted shells, dip more steeply to the east. At the crest of the ridge there are some few purple shales in evidence and then comes the steep descent towards Bamping over rugged dip-slopes of more limestone resembling that near Heho and containing a few compacted shelly layers and sandy shaly layers.

Bamping-Nongsewik limestone.

From Bamping east there is a low-lying, gently undulating plain, broken further east near Nongsewik by a few isolated low hills and groups of hills. These all show moulded dip curves to the west and scarped crags towards the east with low dips in a light grey limestone resembling that of Thamakan. It shows a slight tendency to a more crystalline condition. Away to the east the vast plain, dotted with a few hills, continues. It undulates and is grass-grown with a few clumps of pipal trees, etc.

This is the farthest point in an easterly direction that I reached and brings the description of this section to an end.

The limestone zone as a whole.

Considering the great limestone zone altogether as exhibited in the cart-road section we see that with a tolerable uniformity of strike, and with locally recognizable dips and successions of the strata, there are still great gaps at important places and much uncertainty as to the amount of repetition and re-duplication by faulting and folding, especially along the areas of brecciated rock. It is, therefore, impossible to rationally build up a continuous section with all the strata arranged in correct stratigraphical succession. We can only guess as to the proper relative position of many of them. For the same reason it is impossible to gauge the thicknesses of the limestones individually or collectively. We know that they must be very thick, as their base is never reached, but that is all.

There is, however, a certain surface succession to be made out among them in the area between Thamakan and Nongsewik. There is a large central part characterized by fossiliferous bands of middle productus limestone age. On the one side of it, east of Heho, and on the other side of it, east of Möng Pawn, there is a peculiar rather well-bedded limestone with faintly preserved layers of unrecognizable compacted shells, whilst outside each of these again come the similar pale grey limestones of Thamakan, on the one hand, and Nongsewik on the other.

The surface symmetry of this arrangement can only be pointed out here. When more and better sections and detailed work have been accomplished the above may be found to harmonize with some plausible theory as to the full order of sequence of all the strata and the particular nature of the earth-folds that are responsible for that arrangement.

Other sections.

Besides the extended cross-section along the Government cart-road just described, my subsequent work in this zone includes (*a*) a few cross and strike traverses north of Thamakan extending as far as Myinkyardo and Bawzaing; (*b*) a route traverse along the strike south of Thamakan to Loikaw in Karenni; and (*c*) a long cross-section in Karenni from the Salween river to near Yado—a distance of about fifty miles in a direct line. The last, it was hoped, would have proved most important, as it was a parallel traverse to the one along the cart-road, and I naturally hoped to again pick up the same sequence of rocks as on the cart-road. Such, however, was by no means realized. The other two sets of minor traverses may first be described.

The Thamakan limestone with shale bands is known to extend northwards as far as Myinkyardo and probably much farther. The comparatively level sweep of country by Kyon, Nankon, and Myinkyardo shows here and there this limestone emerging and forming lines of rocky heights. These enlarge and close up somewhat towards the west edge of the plateau and then the country rapidly falls away in riven and shattered scarps to much lower levels. The same limestone and shales as seen in the scarp east of Thamakan, and facing the Heho valley, take a parallel northward direction as far as Pwehla and the low hills east and north of that place. The Pwehla line of scarps are very prominent, while the low barren and waterless hills to the east and down to Kyauktat are obviously (as illustrated unmistakably by their curves) onward flowing billows of the same gently flexured limestone as they gradually descend towards the northward and north-westward continuation of the Heho limestone.

The mass of elevated hilly country between Myinkyardo and Pindaya is of the nature of a much disturbed anticlinal and is composed of limestone and shales generally of the well-bedded Heho type with compacted shelly layers. The same appears to hold for the hills east of Pindaya forming the Bawzaing group, and those east of Kyauktat running down to Heho. Some of the limestone, however, immediately west and two or three miles to the north-east of Pindaya contain recognizable crinoids and corals resembling those of the middle productus limestone group further east. In general, however, beyond the immediate neighbourhood of Thamakan, either north or south, the evidence for any good distinction among the limestones is, as already stated, very weak owing to want of good sections.

Similar limestones and shales without any characteristic distinctions, but plainly belonging to one or other of the three nominal divisions, extend for long distances south of the Thamakan-Mông Pawn cart-road, and compose the greater part of the plateau and hilly masses which continue to the south of Karenni. Between Thamakan and Loikaw I only traversed this country along the strike of the rocks, with a few short cross-traverses, consequently the limestone zone was only seen here along the narrow width of a few miles.

But from Loikaw in the Karenni country I made traverses east over high ridges and low valleys as far as the Salween river, down the Salween as far as Ywathit, thence westwards again over the southern continuation of the same ridges to Saulôn and Nwedaung, and thence west-south-west across a complicated hilly mass to Yado. I thus covered a breadth of country 45 to 50 miles wide across the strike. Here also I found that similar limestones and shales with a few quartzites, equally inseparable as to their individual formations, occupy almost the whole country. Their strike continues to be roughly north and south as before ; they pass through the same variations of colour and brecciation as before ; their exact manner of folding is equally indecipherable as before. The only local differences that can be detected are that in a little range of hills immediately south of Loikaw, and also near Saulôn, there occur some limestones and shaly limestones with crinoids, corals, and brachiopods, ill preserved but generally resembling those near Pindaya; and that all sections east of the Pawn river display the limestones and shales, which become gradually more metamorphosed until, at the longitude of Hsataw and Ywathit, snow-white and grey marble take the place of the ordinary limestone, while schistose slates take the place of the thinner-bedded layers. Along the west side of the ridge east of the Pawn there occurs also a band of quartzite and schistose slate and, doubtless the same repeated, in a line from east of Hsataw to Ywathit. It is but fair to add, however, that in some places the rocks are hardly exposed at all, *e.g.*, between Loikaw and a few miles west of the Pawn river where immense blanks occur without a single rock appearing above the surface soil and the low burnt scraggy jungle, and also along the obscure junction line between the great limestone zone and the gneissic zone near Yado, where from the surface soil and weathered surface rock it is impossible to say whether we are upon old weathered quartzitic rocks or the younger purple sandstones of zone 3.

(3) *Purple Sandstone Zone.*

A minor zone of the great limestone one.

As has already been said, the great limestone zone is interrupted by, or inlaid with, one or two minor compositional zones of younger age which are here and there repeated. The purple sandstone zone (or zones, counting its reduplications) is made up of an extremely characteristic set of well-defined strata, sharply contrasting in every way with the great limestone zone with which it is packed. It appears to have been let down by faulting among the limestone zone, or to have been tucked in along certain lines and axes of reversed folds and faults—the one process or the other according to the style and energy of the mountain-building forces.

Age uncertain.

There is only one thing certain with regard to its age, namely, that it is younger than the neighbouring limestones; though there are other things more or less probable which will presently be discussed.

The main band or zone of these rocks is very well seen in excellent exposures along the Government cart-road between a point four miles east of the Pyinnyaung and Kalaw. Shortly after getting through the gorge in the Pyinnyaung limestone and crossing a short thickness of slightly metamorphic pale greenish grey slates and white quartzites with vertical or very high dip, the road turns south-south-east, and follows a long open valley in these purple rocks as far as Nampandet, and then ascends by zigzags to Wetpyu-ye and Kalaw through the same rocks. These purple rocks appear in the section in a sudden manner as if by faulting.

Petrography, lie, etc.

They consist of a very characteristically coloured set of rather soft sandstones and shales, or hardened clays, with occasional conglomerates. Their general colour may best be described as a dark brick-red or chocolate-purple; and as a whole they very greatly resemble many of the Kasauli and Murree beds in North-Western India. This resemblance is so striking that, at the time, I unhesitatingly put them down as of tertiary age, a guess which seemed at first likely to be confirmed by the presence of coal in associated beds which most likely were a southern continuation of the so-described tertiary coal beds examined by Mr. Jones in the vicinity; but, as will be seen later, there is an objection to this view.

As compared with the Pyinnyaung limestone and the associated metamorphic and highly fissile rocks, this purple sandstone group is but moderately disturbed, the dip throughout its complete length being 30° and less, first in towards the metamorphics and then spreading out across the low valley, which, save for the forest, is fairly open and shallow. The slopes facing west are often gentle dip-slopes; those facing east steeper scarps. In some places along this piece of road section, as near Nampandet and Kalaw, the interbedded conglomerates are of considerable coarseness and thickness. They are seen to be an angular or sub-angular conglomerate, the fragments being often very large and composed of harder bits of a similar purple sandstone to those interstratified with them; but a few smaller and more rounded pebbles are of grey limestone. Sometimes along this stretch of country the cuttings expose sandstone of brown-grey or pepper-and-salt colour.

The width of the zone here is about five miles It has an obscure contact with the Thamakan limestone east of Kalaw.

I have met with the same rocks further north at the bottom of the great limestone scarp west of Myinkyardo in the bed of the Panglaung river. The country in between was not examined by me, but from Mr. Jones' notes [1] about the coal of Palaung and Legaung it seems certain that it occurs in rocks of this zone or in the paler pepper-and-salt sandstones and shales which from evidence further south seem to be united with the purple sandstones into a single stratigraphical and compositional whole.

South of Thamakan, during my route traverse to Loikaw, I again struck more of this purple sandstone zone, which presents a sharp boundary running north-north-west—south-south-east along the west-south-west foot of the prominent limestone ridge near Konni and Pinhmi and a few miles east of Leggia. Here it appears to spread out and include three small ranges parallel to the prominent limestone ridge. The two nearer ones are generally of the purple members of the zone, whilst further west in the neighbourhood of Inwun greyer pepper-and-salt sandstones and soft shales with some promising coal beds make up the section. Such dips as are seen are north-east at angles of 30°, but often higher. As regards the purple sandstones and shales and the pepper-and-salt sandstones and shales with coal, I was certainly impressed with the idea that they were only one continuous series, a single stratigraphical unit; and therefore that the coal as found here would naturally represent the coal found by Mr. Jones at Legaung in what he believed to be tertiary rocks. Hence I was inclined to think the resemblance between the purple rocks and the very similar ones of Kasauli and Murree might reasonably be due to the fact of their being actually of about the same age. (Nests and strings of coaly matter are common in the Murree beds). But now comes the difficulty. On comparing my specimens of these rocks, notably the conglomerate and purple sandstone, with some collected contemporaneously by Messrs. La Touche and Datta east of Thibaw in the northern Shan States, it appears almost certain that they are identical, whilst the latter are certainly the same as Dr. Noetling described from the same locality [2] as "red sandstones of undetermined age" which rest whether conformably or not on the blue limestone, and are in turn overlaid by the recognized late tertiary sandstones and clays with coal beds forming the Lashio coal-field.

But Mr. La Touche is inclined to put these with his devonian rocks from some rather obscure fossil evidence. So here we arrive at an *impasse*, where argument is vain. I found no fossils in any of the series except imperfect plant remains in the coal layers; but I think further search there would yield something definite.

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[1] Records, G. S. I., Vol. XX, Part 4, p. 185.

[2] Records, G. S. I., Vol. XXIV, Part 2, p. 103.

The eastern line of junction between the purple sandstone zone and the limestone ridge to the east-north-east begins near Konni and continues as an unwavering line for about 14 or 20 miles and probably further along the route which I followed. Short cross-traverses near this junction at several points showed some remarkable developments of the conglomerate. There are small bands near Leggia and other places, but at Min-ywa and south of it much of the hillside east of the valley is thickly strewn with blocks of the conglomerate which often becomes so full of limestone pebbles that petrologically it is a limestone conglomerate. Near Min-ywa also there were good examples of interstratification of it with the normal purple sandstone,so that no doubt whatever exists as to its connection with them. It would appear almost as if the much brecciated limestone had become disintegrated under weathering and the fragments flung down as a heterogeneous scree-material among the then forming purple sandstones. South-south-west of Min-ywa on the west side of the valley great hills of what appear to be limestone reveal on visiting them (during a cross-traverse to Tigyit) nothing but huge crags and grotesque masses of this conglomerate, which again on the western slopes overlooking the Tigyit valley are found interbanded with the purple sandstones. Even more grotesque are the strange pinnacles and "stacks" of this rock as seen some miles further south in the rugged and jungle-covered country east-north-east of Nanpale.

Beyond this point this particular sub-zone was lost sight of during my marches southward, and I do not know whether it dies out or how it disappears in this direction.

Other sub-zones of it appear, however, at more easterly places, but in less marked ways, as, for instance, from east of Salaung as far as the Salween river and along the valley of the Pawn river from Saulôn northwards. There are also a few patches of what may belong to one of these zones on the Government cart-road a few miles west of Mõng Pawn, and possibly also in the valley of the Pawn just south of Mõng Pawn. Yet, again, it is possible that at one or two places, as at Sanai near Yado in Karenni, there may be representatives of these rocks; but the exposures are too bad for positive identification.

(4) *Sub-recent or Upper Siwalik conglomerates, sands, loams, and clays.*

Approximate age.

The last set of rocks which I have found occurring as sub-zones, or in elongated outcrops among the great limestone zone, show by their general horizontality, by their restriction to the longitudinal valley systems, and by their general appearance of youth that they are either sub-recent or of uppermost siwalik age.

Petrography.

The rocks are sometimes coarse, loosely coherent conglomerates, or hardly solidified pebble beds, with a matrix of sand, the pebbles being very generally hard quartzite, but sometimes limestone. Associated with them are light-coloured sands and pale bluish grey clays and loams, sometimes splashed with red. In a few places a bed or beds of lignite, to which reference will again be made later on in this paper, are found. The whole is either quite horizontal or with only insignificant dips of a few degrees. They spread out and thin away locally along the stretches of level plateau, so that it is often quite arbitrary where their boundaries are placed.

Laterite and other surface rocks.

At many places as near Thamakan their uppermost layers are overlaid by a few feet of laterite which is locally quarried. Along the water-courses which have cut through the conglomerates and sands there is generally a very superficial layer of quite recent clay and loam, flush with the stream banks, and utilized for wet cultivation.

Extension.

The first and most remarkable patch of these sub-recent rocks is found north and south of Thamakan, and lies as a superficial layer over much of the plateau. It gives to the country a soft and rounded appearance, except where the present stream-beds have cut back among it leaving steep-sided nullahs in their wake.

At the latitude of Thamakan these sub-recent rocks are about seven miles wide at their greatest from west to east. North of that they narrow down to a point at Pwehla and south of it come to an uncertain end near Ngon-thon. They are probably some few hundreds of feet in thickness at the most. In general appearance they strongly remind me of the uppermost siwaliks of the Himalayas.

In the Heho and Sinhe valleys the cart-road exposes no certain examples of the conglomerates and sands. At Hopông there is a very thin layer of them ; but in the Pawn valley round about Möng Pawn, and apparently stretching up and down the valley for long distances, they appear again in strength making a rounded and flowing valley bottom among which the Pawn and its tributaries run. They even invade the side valleys to the west of Möng Pawn, and so are cut into here and there by the cart-road for a few miles west of that place. The flat valley about Tigyit with its lignite may also contain some of these sub-recent beds beneath the present alluvium.

The same sands and conglomerates are also found west of Nwedaung near Daw-shi, but in small quantities. It is possible that at other places in the valley of the Loikaw river they may also be found.

Between the village of Pyinnyaung and the ridge of limestone to the east there are found a few beds of conglomerate and soft sandstones inclined at a high angle and dipping east. Only a very little is exposed along the road just before getting into the limestone gorge. I cannot be sure that they are of the same age, but they possibly may be.

IV.—ECONOMIC GEOLOGY.

The occurrences of useful minerals, and the economic questions arising therefrom, were naturally matters to which I could devote but little time owing to my rapid movements. But I was able to see some few ores and other minerals, specimens of which Mr. C. E. Browne had been getting together for some time ; and later on I had the opportunity of visiting many of the localities in his company.

(*1*) *Coal and Lignite.*

As, in the northern Shan States, the development and utilization of the coal of the Lashio field is an economic question of first magnitude, so also in the southern Shan States is the question of the opening up of some source of mineral fuel for a possible railway there. For the settlement of that question detailed work with that object alone is required. Such rough notes as I have made in my opinion do no more than show that the matter has certainly not yet been finally disposed of in the negative.

The coal and lignite of parts of the Meiktila District and the southern Shan States formed the subject of a paper in the *Records*[1] by the late Mr. E. J. Jones under the following headings: (2) The Panlaung Coal-field, pages 177-188; (3) Two coal localities in the Shan Hills, pages 188-190; and (4) On lignite occurring near Thigyit near Nyaungwe, pages 190-191. Although the coal of the Panlaung field (supposed to be of tertiary age by Mr. Jones) was good as regards quality, Mr. Jones concluded that it was only found irregularly and in pockets. As regards the two localities in the Shan hills, the coal of the Legaung outcrop has much the same quality as that of the Panlaung field; and, though he does not give any geological data, it seems probable from my own observations to the south and north that it is found among beds of the same zone of formations, namely, my purple sandstone series. The second locality given by Mr. Jones of Ngu, 7—9 miles north-west of Pwehla, I have identified as the place now marked on the one-inch maps as Ngot-ko-Yagyi. The black material is found half-mile east of that place in a band of white quartzitic sandstone among massive limestone of the Heho type, which in places show traces of fossils. It is evidently of quite different age to the other coals of the Panlaung field and of Legaung. As analysed in the Geological Survey Laboratory it only gave 4·62 per cent. of fixed carbon. I found the stuff is locally believed to be plumbago, and a prospecting license has been applied for by a Chinaman. It apparently is a much crushed and sheared carbonaceous or graphitic shale, and is of no value as a fuel, whatever may be its value as "plumbago" to the enterprising Chinaman. It is about 10 feet thick, and dips west at 60° to 70°. A similar material is said by Mr. Browne to be found north-east of Thit-e-bin near Pindaya.

The lignite locality of Thigyit given by Mr. Jones belongs to neither of the two zones of formations above, but belongs to the sub-recent sands and clay filling the Thigyit valley, and as such is no doubt a southern continuation of other similar beds in the sub-recent or upper siwalik sands, etc., of the Thamakan plain, to which I shall again refer presently.

Another coal locality not mentioned by Mr. Jones was visited by me on the information supplied by Mr. Browne. It is just east of Paya-byu (Po-pyu of the 1-inch maps) near Inwun and lies about eight miles south-west by south of Thamakan. The coal occurs in several thin bands among the pepper-and-salt sandstones and shales which I have described above (page 145) as following in apparent conformable sequence and forming a part of my purple sandstone series. The series is dipping at high angles of 70° to 80° north-east by east, and occupies the lower slopes of the 4,886 feet hill (1-inch maps). A fairly continuous section is exposed in the stream-bed for about 600 yards above the valley. There are several layers of carbonaceous shale, three of coal 6 inches thick, one of coal 1½ feet thick, and one of coal 3 feet thick. From observations made in the stream-beds to the north and south of this section, it seems likely that the series is fairly continuous along the strike. The coal appears to be very good but friable. When Mr. Browne first visited this locality the coal was burning in one excavation, and a large concourse of people had assembled declaring it was the fire of hell (nga-ye-mi) escaping. Mr. Browne put out the fire with water, comforted them, and they dispersed to their homes.

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[1] Records, G. S. I., Vol. XX, Part IV, 1887.

I have little doubt but that this coal is a southern continuation of the same beds and the same series as Mr. Jones examined in the Panlaung and Legaung localities.

Outcrops of lignite similar to that of Thigyit occur among the sub-recent sands and clays in a horizontal layer at a point half a mile south-west of Nangon near Pwehla, and also at another place in the same neighbourhood 1¾ mile west-by-south of Nangon. It seems probable that a more or less continuous layer of it exists among these superficial rocks; but it does not seem to be very pure or very thick.

(2) *Copper.*

Copper ore in the form of antimonial tetrahedrite (sulphate of copper and antimony) with azurite and green carbonate and with small quantities of arsenic, iron, zinc, silver and lead,[1] occurs at a number of isolated places round about Yataung Hill, which is four miles north-east by north of Myinkyardo. Some prospecting licenses have been applied for. At one place, Ganaingya, 1½ miles due south of Yataung Hill, I saw surface working going on, having recently been started by Ganapatty Pillay of Moulmein, the ore being as described above. The ore occurs in limestone of the Heho type dipping west by north 30°. It is in thin veins running with the bedding on the east side of the hill. I was informed that more of this ore exists also at Mene-Taung and A-le-Chaung (localities a few miles away).

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[1] As determined in the Geological Survey Laboratory.

Copper ore is also said to be found four miles west-north-west of Magwe near Kalaw and also in the stream-beds running to Kwe-ma-sa, south of Nampandet.

(3) *Gold.*

I saw no gold *in situ* during my tour, but it is said to occur about 4½ to 5 miles west-north-west of Magwe (near Kalaw) in the Thamakan State. The occurrence is in a quartz vein. Gold is also said to be washed for in the stream-bed north and north-west of the same place.

Gold is also said to be found in the Baw State in the hills between the Zawgyi river and the Myitnge river. It is in the form of dendritic crystals and flakes in cavities along with quartz crystals in quartz rock or gneiss. The hill is about 3,000 feet high and lies about ten miles north-east of Myogyi town.

(4) *Lead.*

The argentiferous galena of Bawzaing and the native methods of smelting and cupelling it have been fully described by Mr. Jones in his paper above cited, and need not be detailed again here. Several mines round about are being worked now by Chinese firms, the chief localities being :—

- 1¾ mile east-south-east of Bawzaing.
- 2½ miles north-by-east of Bawzaing (the Siszet mine), a poorer ore, but containing much more silver.
- Kyauk-ku-leywa State, in the hills (latitude 20° 55′, longitude 96° 40′) away from all villages. It is worked by the chief of the Pwehla State.

The following mines are not worked now :—

- 1½ mile east-south-east of A-le-Chaung and 4½ miles north of Myinkyardo.
- Pakin, about 1½ mile north-north-west of Bawzaing.
- Meiktila district near Pyinnyaung 29 miles on the cart-road from Thazi to Taunggyi.

(5) *Pyrites.*

Pyrites is dug for the manufacture of sulphur at Yebok in the Pwehla State, and also at places in the Bawzaing State.

(6) *Saltpetre.*

Saltpetre is manufactured at Nam-tok from the nitrate-impregnated soil gathered beneath the surface of the stalagmitic floors of caverns at the foot of the limestone hills north of Nam-tok.

(7) *Tin.*

Tin ore (found by Mr. Holland to be cassiterite mixed with a certain amount of wolfram), is gathered at the villages of Mawchi, Lekhalu, and Re-ho-hku in the Bawlake State, Karenni. As described by Mr. W. G. Wooster, Assistant Political Officer of Karenni, the ore is washed out of the soil by water gathered during the rains in tanks above. I was not able to include a journey to these places in my tour. Mr. Holland reports of the specimens sent in to the Geological Survey Office that both the ore and purified metal are of excellent quality.

(8) *Tourmaline (green).*

Some beautiful transparent dark emerald-green crystals of the above were shown me by Mr. Hildebrand at Thamakan. They had come from a locality known as the 'green stone tract' near Namon in Karenni, on the west bank of the Salween river about thirteen miles north of Ywathit. They had been locally and wrongly identified as green augite (diopside), but I believe were supposed by some to be true emeralds. To make certain I despatched a packet at Mr. Hildebrand's request to the Geological Survey Office for determination, with the result that they were pronounced to be green tourmaline as I supposed. Later on I visited the locality with Mr. Wooster and found a small settlement of miners at work digging and washing for them. The stones are very beautiful in appearance, all being bounded by natural and brilliant crystal faces chiefly of the rhombohedron and prism. In size they vary from that of a pea to that of a small bean. The surface soil of the country, a brown sandy clay with pisolitic ferruginous concretions, on the hill-sides among the blocks of crystalline limestone, is everywhere to the north and west of the little mining village dug into little holes and trenches. The sandy material is taken out, gone over by hand, and finally washed in the stream-bed. From the unrolled appearance of the stones I concluded that their matrix must be somewhere near in the crystalline limestone, and further search showed this to be the case. I was able to bring away pieces of a handsome white marble with the green tourmaline embedded in them. Packets of 10 or 12 rather large stones were shown me which the possessors declared would fetch R300 to R500 in Rangoon. But this seems to me to be a fictitious value probably due to their being at present successfully passed off as true emeralds. Their absolute market value will doubtless in time descend to something much more modest than this ; but they will always have a certain intrinsic worth as pretty stones suitable for ornaments and setting in rings, etc.

Preliminary Report *on the* Geology *of the* Ganjam District, *by* F. H. SMITH, A.R.C.S., *Deputy Superintendent, Geological Survey of India.*

The Ganjam District has practically never been geologically surveyed. A small tract to the extreme south, round Chicacole and Parlakimedi has been mapped by Mr. F. Fedden, and one or two notes have been recorded as to the prevalence of granitic rocks in the Berhampore neighbourhood; otherwise the country has remained unexamined. During the field season of 1899-1900 I traversed some 7,500 square miles, comprising the whole of the Ganjam District with the exception of the small area above mentioned.

Topography.

The Ganjam District may be divided, roughly, into two equal parts; the eastern half, or coastal region, consists of a plain, almost entirely under rice cultivation, thickly dotted with isolated rocky hills and small ranges up to 2,000 feet in height. The western half, known politically as the "Agency tracts," is an area of raised hilly country from 1,500 to 5,000 feet in altitude. The hills are the Ganjam Malias, which form the Ganjam section of the Eastern Ghâts. Travelling amongst them is restricted entirely to a few Government roads; and they are very malarious, fever attacking with special virulence natives of other parts of India.

General geology.

The whole of the Ganjam District is composed of crystalline rocks which may be divided into two main groups; (1) A complex mass of crystalline igneous rocks, varying considerably in composition, texture, and foliation; and (2) a series of bands of more or less crystalline schists, which are crushed and folded into the igneous rocks. The first group covers by far the greater area of the two.

No unaltered sedimentary rocks are met with, but considerable areas near the coast are covered with laterite, and amongst the Malias certain patches of hills are capped by it.

CRYSTALLINE SCHISTS.

The schist evidently represents a more or less metamorphosed series of ancient sedimentary rocks, originally consisting of ferruginous, shaly sands and grits, with bands of impure limestone. In places the schist passes gradually into these sandy and gritty forms, but usually the latter have been entirely altered, chiefly by dynamo-metamorphism, into true crystalline rocks, of which the commonest form is a quartz-garnet schist always rich in sillimanite.

The rock varies greatly in its degree of alteration, and it shows every gradation from an earthy, decomposed quartz-hæmatite schist to an extremely compact, pure quartz, and garnetiferous rock. Besides sillimanite, various accessory minerals are of constant occurrence, of which the chief are felspar, mica, graphite, epidote, and rutile.

Mineral limestone.

The original calcareous beds are now represented by several interesting bands of highly crystalline impure marble amongst the schists. This is always rich in accessory minerals, which are often in such abundance that they almost entirely replace the calcite. About two miles to the north-north-west of Purshottapur two bands of this rock, varying from a fine-grained mineral limestone to a handsome coarse-grained marble, occur, folded amongst the quartz-garnet schists. The rock is essentially a crystalline limestone containing much yellow-red garnet and pale-green diopside; microscopic examination reveals the presence also of quartz, felspar, tremolite, apatite, epidote, sphene, and rare tourmaline.

A band of a very similar rock occurs under the same conditions in the hill-shoulder above Worradamooli, near Kallikota. This is a fine-grained dioritic-looking rock consisting of quartz, felspar, diopside, scapolite, sphene, and apatite.

Occasional exposures of similar diopside-bearing rock are seen amongst the Malias, always occurring as bands of slightly varying composition associated with the quartz-garnet schist.

Spinel-bearing rock.

Another form of the schistose rock occurs in the vicinity of intrusions of coarse pegmatite, and this is evidently due to some extent to contact action. In the Mussellkonda neighbourhood veins of micaceous pegmatite are found, near which dark ferruginous bands are seen in the schist. They consist of a granular rock composed of garnet, magnetite, spinel, augite, plagioclase, enstatite, quartz, and apatite. A similar rock is seen in the boundary range, six miles north of Kallikota. This is composed chiefly of garnet and magnetite—the latter passing imperceptibly into dark-green spinel, which is speckled with minute magnetite grains—with scattered grains of quartz and hypersthene.

Mode of occurrence.

The igneous rocks which form the main groundmass of the whole district are frequently seen to be extremely crushed and foliated, and much of this crushing has taken place since the solidification of the rock. The folding that then occurred evidently enveloped large masses of the overlying sedimentary rocks, now only represented by the bands of schist, which remain amongst the granites and gneisses. The subsequent metamorphism undergone by the folded bands appears to have been almost entirely due to pressure and only in a very small degree to contact action. Intrusive granite is found in one or two localities, notably near Russelkonda, but as a rule igneous intrusions of any kind are extremely rare, and in the great majority of the schistose bands they are never seen.

The bands of mineral limestone appear to form subsidiary layers amongst the ordinary schists, and to have been originated at the same time, and by the same agency as they were. The marbles are very similar in appearance and composition to the ruby-bearing rocks of Burma; but they have been carefully searched both in the field and under the microscope without any trace of ruby, sapphire, or ordinary corundum being discovered.

The junction between the schists and the surrounding crystallines is very seldom seen. The hills are always covered with thick jungle, and the schists weather very readily into a red ferruginous soil, which effectually conceals their boundaries. Occasionally in the outlying rocky hills the two series of rocks are found in contact, and then the junction is seen to be one of gradual passage. The schist becomes more crystalline towards the edges, passing into a true gneiss, which soon becomes indistinguishable from the surrounding granite. The two rocks have apparently been crushed together along the boundary, and passage bands have thus been formed.

Distribution.

There is a conspicuous difference in appearance between the hills composed of massive crystalline rock, and those composed of schist, and the distribution of the two series can be easily seen at a distance. The igneous rocks, especially the coarser granites and gneisses, form bold rocky hills strewn with boulders, often capped by great domes of bare exfoliating rock, or precipitous castellated peaks. The schists weather into smooth, red, soil-covered slopes, overgrown with low bushes. The rocky hills are frequently seen to be so seamed and banded with the red schist-bands that it is impossible to map the two groups accurately.

The foliation strike of the schists is most inconstant, the bands running in all directions. In the eastern part of the district the dip of the foliation planes is often low, and the strike varies widely; but to the north and west, in the hill tracts, the foliation is practically always vertical, here the variation in strike is usually limited, ranging between north to south, and north-north-west to south-south-east. Schistose bands are found scattered impartially over the whole of the Ganjam District, and locally they occupy fairly large areas. In the southern half of the Malia Hill Tracts the schist is somewhat infrequent. Over the coastal region the distribution is very even, but one large patch of schists occurs between Ganjam and Kallikota, stretching from the coast for some twenty miles westwards inland. The northern end of the Malias also contains extensive bands of schist. The largest of these, covers the extreme western prominence of the Ganjam District, to the west of Tumriband and Kotgar. The latter area is interesting on account of the curious formation of the hill-ranges. A hill tract, some fifteen miles in length by ten in width, and rising to 4,000 feet in height, is entirely composed of quartz garnet sillimanite schists, with vertical foliation and north to south strike. The summits of all the ridges are formed of the remains of a once continuous, horizontal laterite cap, up to about 200 feet in thickness. The view from the top of any of these ridges is curious, every hill-range is approximately of the same height, and the top is perfectly level for long distances. The country was evidently once covered by a laterite plateau, which has been carved and gradually cut out by denudation, leaving the tops of the ridges alone of laterite, while the flanks and valleys are of schist. I have found hills of identically the same description eighty miles to the north-west in the Sambalpur District, in the Central Provinces, notably the Gandamardan or Narsingnath range in the Borasamar zamindari. There a bold range, over 3,000 feet in height, of exactly similar rock, is capped by a horizontal plateau of laterite, from which the sacred stream of Narsingnath springs. Mr. V. Ball [1] also mentions several similar ranges, with flat laterite caps, which occur in the intervening Kalabandi State.

Age.

There is no evidence in Ganjam by which to determine the age of the schists. They have a general resemblance to the rocks of the older transition series, but none of the typical Dharwar forms are found amongst them. There is no doubt that they are identical with the rocks of the Gandamardan Range, and the latter have the advantage of occurring within a few miles of beds of Cuddapah, or lowest Vindhyan age. The latter are shales and quartzitic sandstones, which are quite unaltered. So it seems safe to assume that the quartz-garnet schists are of considerably greater age than the Cuddapahs.

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[1] Records, G. S. I., Vol. X, Part 4, p. 169.

CRYSTALLINE IGNEOUS ROCKS.

The main foundation of the whole of the Ganjam District is a somewhat complex mass of crystalline rocks of igneous origin. By far the greater part of this mass consists of garnetiferous granites or granulites, but amongst them are found various bands and dykes, usually of more basic character and containing rhombic pyroxene, of which the following are the chief: pegmatite, biotite gneiss, hypersthene granulite, varying from acid to almost basic forms, and representing the charnockite series; augite, mica, and hornblende diorites.

Amongst the rocky hills, covered with soil and thick vegetation, it is practically impossible to make out the relationship of the different rocks to one another. But it may be generally stated that pegmatite, and most of the diorites are younger intrusive rocks. Some few of the diorites, and the hypersthene granulites, are older than these, and of the same age, or perhaps a little younger than the main granites, from which the biotite gneiss has been locally derived.

Garnetiferous granitic rocks.

The most common form of the granite is a coarse-grained rock chiefly composed of quartz, with plagioclase felspar, garnet, and usually more or less biotite. The composition does not vary greatly, and then only as regards the amount of ferro-magnesian constituents. The texture and foliation vary widely. The finer-grained varieties appear to weather the more easily and they seldom give rise to bold features of the country. The coarse rock forms the great boulders and broken scarps which are so common throughout the granite hills, and its texture is frequently very coarsely porphyritic, containing crystals of felsar up to 6 and 8 inches in length. The coarse rock is also conspicuous when strongly folded, the porphyritic crystals being pressed out into flat patches of broken fragments. The biotite gneiss is a crushed form of the non-garnetiferous granite.

Granulite.

A very common form of rock is fine, or medium-grained and strongly-foliated, containing dark layers of garnet amongst white layers of quartz and felspar. This represents the typical form of "granulite," and it passes insensible into the charnockite series by the inclusion of rhombic pyroxene, usually in the form of hypersthene. In the field it is often impossible to tell from the appearance of the rock whether it is hypersthene-bearing or not, and there is every gradation between the ordinary granulites and the true, almost basic charnockites.

Hypersthene granulite.

The hypersthene granulites are seldom seen to be banded or foliated in the field, but under the microscope they are nearly always seen to be much crushed, the constituent grains often being almost mylonitic, and showing evidence of great strain.

The more acid hypersthene granulites have a very characteristic appearance. They are of a general greyish colour, but if looked at closely, the rock is seen to be coloured bluish by milky quartz and pink, or red by garnets scattered through it. Garnet seems to be a constant constituent throughout the acid forms, but it decreases gradually and dies out entirely from the more basic rock. The former generally consist of quartz, plagioclase-felspar, garnet, hypersthene, biotite, and magnetite.

The acid forms pass gradually by the inclusion of more and more rhombic pyroxene, into a dark lustrous rock, of greenish or brownish black colour and more or less basic composition, though it still contains a considerable amount of free quartz. The constituents are generally plagioclase, quartz, hypersthene with enstatite and augite—biotite, apatite, and occasionally epidote.

The hypersthene granulites are so intimately associated with the surrounding granites that it is very difficult to tell what is the relationship between the two. The former appear generally to be banded in amongst the granites, and to have shared to varying extents in their crushing. The acid hypersthene-bearing rocks would suggest the mixture of the original magmas in a more or less molten state; while the more definite bands of basic charnockite were probably intruded into the granite after the solidification of the latter. But it seems probable that the age of the two is very much the same. Many of the rocks which appear to be coarse garnetiferous granites, prove to contain pyroxene, and they are sometimes seen to be intrusive. An interesting exposure of this kind occurs about a mile to the north-east of Bigupudi bungalow. A low dome of massive rock is found to be composed of extremely coarse, porphyritic pyroxene granite, containing felspars up to 1 foot in length. At the sides and end of the dome, the rock becomes more fine-grained, with small crushed porphyritic felspars; whilst at the edge the rock is extremely fine-grained and is seen to be composed of a mylonitic groundmass of plagioclase and quartz with crystals of enstatite, magnetite, and epidote. The coarse rock appears to have been an ancient intrusive mass, which has withstood the crushing that has gone on around it.

Fine-grained augitic rock.

There is another form of more or less basic augite-bearing rock, which seems to be quite distinct from the charnockite series. It is always very fine-grained and it appears in two forms, occasionally as an ordinary intrusive dyke, but more frequently crushed and mixed into the coarse granitic rock. In the latter case it is impossible to tell which of the two is the older, they are so intimately interbanded and interlaced, that each in turn appears to be intrusive upon the other. This rock is chiefly developed in the neighbourhood of Aska. It occurs throughout the hill mass a few miles to the south, interbanded and mixed with coarse granite, and again eastwards round Boirani, in a slightly modified form, in the form of dykes amongst highly-crushed coarse gneiss. The rock to the south of Aska is found to be a typical 'Kersantite,' being a fine-grained granular diorite, composed of plagioclase, augite, biotite, quartz, and magnetite. As might be expected from the mode of its occurrence, it shews signs of strong crushing. The dyke rocks of Boirani have a slightly different composition,—plagioclase, quartz, enstatite, magnetite, and epidote—but they are very similar in appearance to the Aska Kersantite, and they have undergone subsequent pressure to an extreme degree, the quartz and felspar being crushed to a mylonitic mass. Similar rock is occasionally found amongst the Malias, banded with the granites. It is quite distinct from the more recent dykes, which are not crushed, and it evidently represents an older intrusive rock which has subsequently been folded and crushed amongst the surrounding granitic mass.

Trap-dykes.

Unaltered trap-dykes are very rare throughout the whole district. A few of small extent are seen amongst the Malias. These are of fresh dioritic rock, and they are evidently of comparatively recent age. The dyke-rock is a hornblende-diorite consisting of somewhat granular quartz, plagioclase, hornblende, and some rhombic pyroxene.

Hot springs.

In one or two places warm sulphurous springs rise amongst the crystalline mass. The best-known of these is the 'Taptapani' which rises in the hills, about 8 miles to the north-west of Poramari. It is a small spring of slightly sulphurous water, about 115°F. in temperature, in which a constant stream of bubbles of sulphuretted hydrogen rises. It is situated in the midst of massive granulites, and as in the other cases, there is no evidence to determine its origin.

Age of crystallines.

The mass of the crystalline igneous rock, granites and granulites, is evidently of great age. It presumably formed the foundation, whereon were laid down the sedimentary beds, from which the schistose bands have been formed, a supposition which gives the crystalline igneous rocks an age considerably greater than that of the schist.

The foliation of the igneous rocks, like that of the schists, is very variable in direction, and the folding of the rocks appears to have been due to local causes rather than to any one great and wide-spread disturbance. It would seem that at a remote time, previous to, and during the 'Transition' period the igneous rocks were subjected to strong local disturbances, which resulted in the crushing and banding of the hypersthene granulites, and of the older intrusive rocks, and also in the folding and inclusion of bands of the overlying sedimentary rocks, subsequently altered more or less completely into quartz-garnet schists. Since these disturbed times the country has been at rest, and the few more recent dykes of intrusive rock, which have succeeded in reaching the surface, are still fresh and unaltered in every way.

Laterite.

A good deal of the country near the coast is covered with irregular deposits of laterite, which weathers into a somewhat barren red soil. The laterite is of no great thickness, being often only a shell of a few feet, underneath which decomposed and weathered rock is often visible. The latter appears to be invariably the quartz-garnet schist, from which the laterite is directly derived. The coarse granitic rocks are never seen to have any connection with the patches of laterite.

Besides this low-level laterite, a similar vesicular, ferruginous clay is found, capping the western extremity of the Ganjam Malias at a height of about 3,500 feet. This high-level laterite cap has been already referred to as exactly similar, and overlying similar rock, to that of the Gandamaidan range in Sambalpur, and like the latter it contains the chief water-supply of the surrounding country, springs arising all along the lower edge of the laterite. This cap seems to be the eastern extension of the high-level laterite which occurs throughout peninsular India, but it is noticeable that its occurrence is limited to the areas occupied by the quartz-garnet-schist, which alone of the Ganjam rocks seems to pass directly, by decomposition and concentration of the iron, into laterite.

MINERALS.

Ganjam has often been credited with the possession of valuable mineral resources. Sapphires and gold have been mentioned as occurring in the district, and the occurrence of workable deposits of manganese in Vizagapatam to the south has led to the hope that the same mineral might be found in Ganjam. Unfortunately the examination of the country shows that valuable minerals, with the possible exception of mica, are not to be found in the Ganjam District.

In one field season it is, of course, impossible to carry out detailed prospecting over so large an area, but during my tour no minerals of economic value, except mica, have come under my notice, nor could I obtain any information of their existence in the district, from the local authorities or from the villagers themselves.

Manganese.

As far as I could discover there are no traces of manganese in Ganjam.

Iron.

Amongst the Malias there are a few native iron-workers, but they usually procure their iron already melted. Smelters are only found in one or two localities where they procure a soft earthy hæmatitic ore from the laterite.

Graphite.

Graphite has been mentioned as forming a rich graphite-schist on the east coast of India. It does occur in most of the quartz garnet-schists, but only as minute specks scattered through the rock, visible as brilliant silvery grains. The total amount of graphite is quite insignificant.

Gold.

One of the chief objects of my work in Ganjam was the discovery of gold, but I was unsuccessful in finding any gold-bearing reefs in the district.

Quartz reefs are almost entirely absent throughout the whole of the igneous crystalline area. Occasional small veins of white quartz are met with, but no trace of gold is to be found in them. A more hopeful-looking rock is seen in one or two places amongst the schists. It is an opaque or iron-stained quartzose rock, forming a band amongst the garnetiferous schist, but it also gives no trace of gold on testing, and no visible gold is obtained when the rock is crushed and washed.

I was informed that gold-washing was carried on in the streams round the foot of Mahendragiri, but on my arrival there the villagers and the local authorities knew nothing of it. Near the summit of Mahendragiri, I found one grain of gold while washing the sand of a small stream. But no more gold could be found, and no quartz reef was to be seen in the neighbourhood.

Amongst the Malias the hill tribesmen do not attempt to wash for gold in the streams and there appears to be no gold in them.

Sapphire.

Sapphires have been reported as occurring in the Ganjam District; in fact, a packet of small stones, described as coming from the Mahendragiri Mountain, were sent to the Office of the Geological Survey in Calcutta for determination. They were found to be sapphires, of a fine blue colour, transparent to translucent, and of considerable value. I spent a day or two on the summit of Mahendragiri, unsuccessfully searching for such gems, and I then learned the true history of the stones, some of which had found their way to Calcutta. Mahendragiri is almost the highest hill in Ganjam, 4,923 feet in height, and is well known as having several fine temples built on its summit, as well as many small shrines and monoliths. This is probably sufficient to connect the hill in the popular mind with visions of buried treasure. It appears that some fifteen years ago, a trader, described as a 'Kabul merchant,' spent some days on the summit of Mahendragiri digging in the mounds, on which the small monoliths generally stand. The earth extracted was sifted, and the trader brought down some fine gravel with him, from which about sixty sapphires were picked out. These were eventually cut and polished in Madras, and pronounced valuable. The trader hoped for a reward from the Mandasa zamindari in which Mahendragiri is situated, but whether he took the stones up with him, or whether he had previously obtained information as to their hiding-place seems uncertain.

The mass of Mahendragiri is composed of garnetiferous granulite which passes into a very coarse, porphyritic garnet-granite near the summit, whilst the actual ridge consists of a band of hypersthene granulite. There is no trace of corundum, or sapphire, to be seen throughout these rocks, nor could I find any gems in the sands of the small streams which traverse the hillsides. I carefully washed the earth which remained in the mounds, but with no better results, so it would appear that all the sapphires had been successfully extracted.

As has been already mentioned the mineral limestone of Purshottapur does not yield any trace of ruby or sapphire.

Mica.

The only mineral in Ganjam of possible value appears to be mica, which has been known for some time to occur in the neighbourhood of Russellkonda. It has been extracted in small quantities, from time to time, by native physicians, who value it highly as a general medicine after it has been burnt and finely powdered.

The chief locality where mica is found lies a few miles to the south-west of Russellkonda, in a strip of jungle-covered country between the Russellkonda-Aska road and the hills to the west. The mica appears at the surface as broken and frayed flakes amongst a loose gravel. These exposures are fairly frequent, and there is no doubt that many new outcrops might be discovered if the country were systematically searched.

The mica is a constituent of a coarse, more or less micaceous pegmatite, which occurs in irregular intrusive veins amongst the surrounding rocks. The latter are usually fine-grained granulites, but in one or two instances the pegmatite intrudes into quartz garnet schist. The composition of the pegmatite is capricious and varies very rapidly, and a vein which is highly micaceous at one point is frequently found to be composed of quartz and felspar only, with occasional tourmaline, at a few yards' distance. I selected the three richest outcrops of mica, on which to sink pits, in order to determine the quantity and quality of the mica in the fresh rock below, and these three pits were sunk at the villages of Goradandi, Bodiamba and Jillundi.

The results are not very encouraging as regards these three particular exposures, though mica of fair size was discovered. But the fact remains that this country is seamed by veins of coarse micaceous pegmatite, which, if only the right locality could be found, is quite likely to yield valuable mica, as it does further to the south in Nellore.

Goradandi.

The Goradandi pit was sunk in a dyke of coarse pegmatite, 30 feet in width, running north and east. The dyke can be roughly traced on the surface for a distance of 100 yards, but it is only highly micaceous in one place. Here, in a coarse granite, somewhat decomposed and kaolinised, mica-crystals are found up to 3 inches in diameter. The mica is broken and dirty, and it contains frequent small quartz-crystals. The quality does not improve below, and the lateral extent of the micaceous rock is only a few yards.

Bodiamba.

At Bodiamba a band of highly micaceous gravel was seen, in which a trench was dug, but on reaching the underlying pegmatite, it was found to be entirely unproductive.

Jillundi.

Near Jillundi on the Russelkonda-Aska road mica had been extracted occasionally within the last few years. The pegmatite dyke cannot be traced at all on the surface, and mica-bearing surface gravel was the only indication of its presence. This pit was the most successful of the three. At a depth of from 3 to 6 feet a considerable amount of mica was found in fairly solid crystals or "books" of irregular shape and up to 5 inches in diameter. The mica is somewhat frayed and earthy, from the results of surface action on the rock. Below 6 feet however the rock rapidly loses its mica, and at 8 feet in depth it passes into almost pure quartz, with rare crystals of felspar.

The mica extracted from the three pits has practically no market-value. The area of the plates is not sufficient—it is barely possible to cut rectangles 3 x 2 inches from the largest crystals, and this size, if pure and clean, has only a maximum value of 2 annas per pound, and the mica is usually dirty and very frequently penetrated by quartz crystals. The micaceous rock, too, in all these cases is very limited in extent. On the other hand it is quite possible, that in this neighbourhood localities may be found where the micaceous rock is developed on a large scale, both as regards its mass and the size of the included mica-crystals.

Coarse mica-tourmaline-granite is also found among the hills about three miles to the north-east of Russellkonda, but so far no mica-crystals of more than 2 inches in diameter have been seen in it.

A Geological Sketch *of the* Central portion *of* Jeypore Zamindari, Vizagapatam District, *by* W. L. WALKER, M.A, PH.D., *Geological Survey of India.*

I.—INTRODUCTION.

Position of area surveyed.

The country which is the subject of the present geological sketch constitutes the central portion of Jeypore Zamindari, and corresponds to that portion of Vizagapatam District which is contained in the north-east quarter of Atlas Sheet No. 93. The area of the country surveyed is about 2,500 square miles. Arriving in Jeypore about 20th November 1899, I carried on explorations till about 20th March 1900, when I returned to Calcutta *viá* Vizianagram. There are very few good roads, or even poor ones, but coolies are easily obtained for transport in this particular region, though in the unsurveyed country to the south neither coolies nor carts can be used, and elephant transport is essential.

Topography.

The eastern part of the country, reported upon as part of the Eastern Ghâts, forms part of a great plateau of about 3,000 feet altitude; to the west it falls gradually from 2,000 feet in the Kotpad region, to about 700 feet south near Salmi. Two rivers rise in the hills to the east, the Indrabati flowing westward into the Bastar State and the Kolab which, after a circuitous course, empties into the Godavari. The eastern plateau consists of low undulating brownish hills, either quite devoid of tree vegetation, or at most poorly wooded in the intervening valleys, while the north-western part constitutes an almost level plain of valuable arable land. Most of the south-western part, from Ramagiri and Modpodor southward, is well wooded with forest, of sâl and occasionally teak, which, in the future, if carefully preserved, will prove to be of immense value. Rock outcrops in the hilly country are very frequent and large, while in the lower country to the west, alluvial deposits and vigorous forest growth conceal the rock formations over large areas.

Geologically four rock groups are readily distinguished:—

I.—The greater part of the region west of the hill range is composed of crystalline schists—biotite and hornblende gneisses—and schists—potstone and quartzites.

II.—The hilly country forming the eastern part of the country surveyed, is made up of rocks which can best be referred to as hypersthene granites, generally garnetiferous and at times showing such marked parallelism, as to be regarded as gneissoid granites, if not simply gneisses.

Rock groups.

III.—The comparatively level country in the vicinity of Kotpad is deeply covered with clay and sand, so that outcrops are very rare, but those that occur, indicate a rock formation of old non-fossiliferous sediments, probably Cuddapah in age. A narrow strip of similar rocks extends south along the Bastar-Jeypore boundary as far as the Tulsi Hills.

IV.—A few isolated outcrops of diabase have been observed, less altered forms near Jeypore, and again quite altered ones near Ramagiri.

This region had never been geologically examined before, and when the adjoining unsurveyed country has been surveyed, a full geological report may be possible, the present sketch being only preliminary. Reference to the geologically coloured copy of the north-eastern quarter of Atlas Sheet No. 93, which accompanies this report [1] will make clear all geological and topographical references contained in the present sketch.

II.—CRYSTALLINE SCHISTS.

These rocks occupy the region between the 3,000 feet plateau, and the Bastar boundary, except for a small patch of Cuddapahs on the extreme north-west and west of the country surveyed.

Origin of crystalline schists.

Professor Rosenbusch recently boldly divided crystalline schists into two classes. Those which in chemical and mineralogical composition are closely related to igneous rocks he designates with the prefix *ortho*, and considers as probably metamorphosed igneous rocks. Other schists, however, are closely related chemically to sedimentary rocks, and these he regards as metamorphosed sedimentary rocks, and he distinguishes them as *para*-schists. We thus have *ortho*-gneisses and *para*-gneisses according as there is reason to believe that the rocks in question are metamorphosed, igneous or sedimentary rocks.

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[1] Not yet published (Dir.).

Ortho-gneisses.

In a general way the schists north of Ramagiri and Guma are of the ortho group, being somewhat coarse granitoid gneisses which in hand specimens would pass for granites. Both biotite and hornblende varieties occur, though the former is the commoner rock. Where not too well foliated, the felspars are large with a porphyritic tendency. The general strike is north-west. The best exposures occur north of Ramagiri, where the rock is so granitoid, that I was at first inclined to look upon it as granite. In the vicinity of Guma and Bagderi this rock is also abundant. (Specimens $\frac{14}{495}$, $\frac{14}{498}$, $\frac{14}{499}$ and $\frac{14}{500}$.)[1]

Potstone.

At numerous points to the west and south-west of Jeypore, outcrops of a coarse grey potstone have been observed. Near Noaput and Outagaon some three miles from Jeypore small quarries have been opened and the potstone hewn for building stone and carved into idols. It is again seen between Bipariguda and Modpodor on the Ramagiri road. The largest masses, however, are found on the Malkongiri road, four or five miles beyond Kolar bungalow. In this last occurrence the rock alternates with quartzites and well-foliated biotite gneisses which have a well-defined north-west strike, dipping from 45°-60° to south-west. The potstone, however, is fairly massive in all the occurrences examined (specimens $\frac{14}{496}$ and $\frac{14}{497}$).

Para-schists.

The schists south of a line from Kolar to Ramagiri belong to the *para* class. Biotite gneisses, very poor in felspar, occur over the country from Kolar to Pangam and northward to Tetulgama and Ramagiri. These gneisses are well foliated and strike north-west, though the dip varies. To a very small extent possibly as crushed synclinals these rocks occur as bands in the ortho-gneisses already described. Hornblende gneiss, pistasitic quartzite, white quartzite, quartz magnetite schist and greyish slaty mica schists occur as subordinate members of the para group of schists.

III.—HYPERSTHENE GRANITES.

Hypersthene rocks.

The hilly plateau country previously referred to forms the eastern part of the country geologically surveyed. The hypersthene series is bounded on the west by the crystalline schists, the irregular line of contact passing about north-north-east through Jeypore. The rocks composing these hills are characterized by hypersthene, generally accompanied by common red garnet, and vary in acidity from norites with a specific gravity of 3·07 (specimen $\frac{14}{450}$) to granites with a specific gravity of about 2·70. When fresh they are of a bluish to greyish black colour. Very coarse and even porphyritic forms occur, but the even-grained dark aphanitic rock is more typical.

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[1] Reference to register numbers of the petrological collection of the Geological Museum, Calcutta.

Previous nomenclature.

These rocks occur commonly in Peninsula India, where they have been studied by many geologists of this department. On account of their forming most of the hill masses of the Peninsula, Dr. King, late Director of the Geological Survey of India, called them mountain gneiss. More recently Mr. T. H. Holland has studied them, and in a memoir, now in press, proposes to call them *Charnockites* in honour of the founder of Calcutta. Lehmann and others have given us very full descriptions of similar rocks from the granulite formation of Saxony, where on account of their close relations with the granulites, they have been variously called, diallage granulites, augite granulites, trap granulites and pyroxene granulites. The last name is now generally accepted for the Saxon occurrences.

I prefer to use a nomenclature having reference to the mineralogical compositions, so that the names indicate the mineralogical composition and general nature of the rocks.

Position of Jeypore occurrence.

In the Hill Tracts of Vizagapatam District a great elliptical mass of these rocks appears to make up the most of the Eastern Ghâts. The longer axis of the ellipse has a north-north-easterly direction, while the area is probably four or five thousand square miles. The minor axis extends from Jeypore to within five miles of Salur, a distance of about sixty miles. The comparatively small part of this great mass, geologically examined during the past field season, constitutes only the central portion of the north-western half of the ellipse.

Structure.

Both granitoid and gneissoid forms occur, though it is very probable that both forms are essentially the same from a genetical point of view. The gneissoid structure appears to have been induced by a pressure, acting at right angles to the major axis of the elliptical mass, and to the direction of the usually imperfect banding or foliation. When examined under the microscope in polarized light, thin sections show that the constituent grains of the minerals of the gneissoid varieties of these rocks are so very free from pressure phenomena, that it is almost certain that the foliation was induced at a time when the temperature of the rock was sufficiently high for it to be fairly plastic.

Hypersthene syenites.

The commonest variety of these rocks is a heavy bluish black massive form which the microscope shows to be granitoid in structure, and composed chiefly of anhedra of hypersthene, and almost equal parts of twinned and untwinned felspars. Next in importance are reddish garnets often idiomorphic, green hornblende, pale greenish augite, quartz biotite, and iron ores, but never sphene. Except the idiomorphic garnets, the other minerals are usually xenomorphic. Gneissoid varieties occur. The specific gravity varies from 2·77 to 3·00. This form may be referred to as hypersthene syenite. (Specimens $\frac{14}{445}$ and $\frac{14}{449}$).

Norite.

A more basic variety in which hypersthene and plagioclose are the chief minerals, and garnet orthoclase, greenish augite, iron ores, and a little hornblende or biotite the accessories, resembles so very closely the ordinary norite, that it requires no special name. In specific gravity it varies from 3·00 to 3·14. (Specimens $\frac{14}{448}$, $\frac{14}{447}$ and $\frac{14}{450}$).

Hypersthene granite.

More acid varieties in which orthoclase and quartz predominate, and hypersthene and the accessories are less abundant, may be regarded as hypersthene granites. These granites in the field appear to pass gradually into varieties free from hypersthene, as is seen in the case of the rocks composing several of the hills between Goserla and Kolar (specimen $\frac{14}{452}$). Here coarse and even porphyritic forms are much more frequent than in the case of the more basic varieties. Gneissoid rocks of this mineralogical composition occur.

Diopside rocks.

In several places, associated with the hypersthene rocks above described, hypersthene diopside varieties were observed. In some a green spinel is present (specimen $\frac{14}{446}$), while in others plagioclase and sphene are particularly prominent. (Specimens $\frac{14}{459}$, $\frac{14}{460}$, $\frac{14}{461}$, $\frac{14}{462}$, $\frac{14}{463}$, $\frac{14}{464}$, and $\frac{14}{465}$). The relationship between these rocks and the commoner forms of the massif above described is very indefinite. Two of the occurrences appear to be close to the border of the great igneous mass, one near Kudbi and the other a couple of miles east of Kolar bungalow. The third outcrop of diopside rocks is near Araku, where numerous small hills are capped with this rock, while the intervening ground is occupied by the commoner forms of the hypersthene rocks. In this last case I do not know the distance from Araku to the border of the massif, as I did not explore farther to the south-east.

Isolated outcrops of hypersthene rocks.

Numerous small hills of the same lithological character as the large massif, not indicated on the accompanying geologically coloured map, lie like islands in the schist complex, at distances up to three or four miles to the west of the western boundary of the main mass. The actual contact with the crystalline schists is nowhere exposed and the boundaries of the islands as well as of the main massif as marked on the geological map, are only approximate at best.

Igneous origin.

I am inclined to regard these hypersthene rocks as forming a great igneous *stock*, though it would be very difficult to prove conclusively that this is the case. My reference to this very interesting group of rocks is purposely brief, partly, because a detailed report can more properly be prepared after the completion of the survey of the great massif, and partly, because they have been so exhaustively studied from various parts of the Peninsula by Mr. T. H. Holland and described by him in a memoir now in the press.

IV.—CUDDAPAH SYSTEM.

The level plain extending from Kotpad to Nowrangapur, and south-east almost to Sashandi, offers very few points for geological observation, but wherever rocks are exposed, they are always found to be non-fossiliferous sediments. On this ground chiefly I have assigned them to the Cuddapah System.

Secondary enlargement of quartz grains.

Near Kaliagura hæmatite quartzite, and ordinary quartzite are met with. The latter rocks in this section show in polarized light beautiful secondary growths of quartz on the old clastic grains. The interstices between the rounded grains of this former sandstone have been filled in by newly-deposited quartz substance, the crystallographic orientation of the new quartz always agreeing with that of the adjacent clastic grains (specimen $\frac{14}{482}$). In several small ravines half a mile west of Sashandi outcrops of purple shales occur. Similar rocks were observed in the bed of the Indrabati river near Aoli. Three miles north of Kotpad, a few loose blocks of a calcareous hornstone were observed, though I was unable to find this rock *in situ*. These outcrops are only sufficient to lead one to suppose that the whole of the deeply alluvial-covered plain, of which Kotpad is the centre, is underlain by Cuddapah rocks. I have mapped it accordingly.

Other Cuddapahs.

Besides the Cuddapahs of the Kotpad plain, rocks of the same group occur along the Bastar-Jeypore boundary from Bansuli, near the confluence of the Jaura and Kolab rivers south-westward as far as the Lokli hills, where the Kolab finally leaves Jeypore territory. This strip of Cuddapah rocks is quite narrow, never more than four miles wide.

Jaura-Kondajori outcrops.

In the Jaura at Bunsuli purple siliceous dolomite is well exposed (specimen $\frac{14}{474}$). The general strike is north-easterly. Again some five or six miles south, near Kondajori small isolated hills of semi-metamorphosed red and white mottled dolomite occur. In some of these mottled dolomites peculiar coral-like structures abound. Though possibly of organic origin they are too badly preserved to enable one even to say definitely whether they are of organic origin or not (specimens $\frac{14}{457}$ and $\frac{14}{477}$). On the banks of the Kolab near Korokpur, and again at Talur purple slates and shales crop out.

Araguda limestone.

Farther south, at Araguda, due west of Ramagiri, the Kolab forms cascades as it cuts its gorge through nearly horizontal, grey, argillaceous limestone. In places the limestone has been dissolved away by the running water, giving rise to phantastic pillars, which are often capped by loose perched blocks, pierced by circular openings, or meeting to form arches. Caverns along the banks of the river are common. A mile or two north, probably in similar rocks (specimen $\frac{14}{478}$), occur the sacred caves of Gupteswar, where Hindu pilgrims assemble in large numbers for the annual feast which is held about the end of February.

Tetulguma conglomerates.

Near Tetulguma the Kolab traverses a highly metamorphosed conglomerate;—the general mass of the rock is a very quartzose mica schist with pebbly bands an inch or two wide and from four to eight inches apart. Within the pebbly bands the matrix of the pebbles is identical with the mica schist of the broad intervening bands, but the flattened pebbles appear to be uniformly of a somewhat more basic material. Were the pebbles and the matrix of the same chemical composition, one might be inclined to regard the conglomerate as of autoclastic origin, but this can hardly be accepted in view of the very different chemical composition of the pebbles and matrix (specimen $\frac{14}{486}$). At Tetulguma, as at Korokpur and Bansuli, the general strike is north-east to south-west.

Doubtful Cuddapahs.

The hills Lekki, Tulsi, and Lokli are not so definitely related to the Cuddapahs. They are, in general, composed of coarse, somewhat friable quartzite, not completely cemented by secondary quartz. On account of the friable nature of the quartzite, I have mapped them as Cuddapahs in preference to including them in the crystalline schists.

Dharwars (?).

Some of the quartzites along the boundary between the Cuddapahs and the schists bear a close resemblance to some of the Dharwar rocks. I thought them worth testing for gold, but on crushing and washing not even a colour of gold was obtained and unfortunately no fire assays were made.

V.—DIABASE.

Diabase.

Some of the small hills close to Jeypore are composed of a black compact rock resembling some of the intermediate forms of the hypersthene series. The microscope discloses it as a somewhat altered ophitic diabase. Some two miles west of Ramagiri similar rocks occur, but in them the augite and plagioclase have been altered, giving rise to an epidiabase. The outcrops are quite unsuited to determine the nature of the geological relationship, though on lithological grounds it is probable that these rocks occur as dykes (specimens $\frac{14}{466}$, $\frac{14}{467}$, and $\frac{14}{468}$).

VI.—DYNAMICS.

It has already been mentioned that the general strike of the oldest group of rocks, the crystalline schists, is north-west. This is the direction of the best foliation, though one often observes slickensides with a north-easterly direction. In the country surveyed the hypersthene rocks without exception strike in a north-easterly direction. Thin sections of the gneissoid varieties of these latter rocks, when examined in polarized light, are usually seen to be so perfectly free from pressure and tension phenomena,—undulatory extinction and granulated borders of quartz grains for examples,—that one is compelled to conclude that the pressure acting at right angles to the foliation of the hypersthene rocks, which induced the foliation, must have acted at a time when the rock was in a distinctly plastic condition and very probably at a high temperature. The Cuddapah rocks when not horizontal, as in the case of the Araguda limestones, or quite massive as are some of the quartzites invariably, have an approximate north-eastern strike.

Two strike directions.

From these facts it may be deduced that the oldest rocks are the crystalline schists, which, before the intrusion of the great igneous massif, or the deposition of the Cuddapahs, were acted upon by an earth movement from the north-east or south-west, giving rise to the north-west foliation, which is quite wanting in the case of the younger groups of rocks. Later the hypersthene rocks were intruded and the Cuddapahs deposited, and a new force acted from north-west or south-east, giving rise to the foliation of these two rock groups and inducing the slickensiding of the crystalline schists. It must not be inferred from this, that when this second earth movement began, that the Cuddapahs were already deposited and that the hypersthene intrusion was taking place. This would mean that the hypersthene rocks are younger than the Cuddapahs, while the earth movement may have acted during a very long period, beginning with the intrusion of the igneous mass and giving rise to the uncrushed foliated rock from the plastic mass, while during the long period of its action the Cuddapahs were deposited, and the same strike imparted to them as had already been taken on by the hypersthene rocks.

Relative ages of the rocks.

It is remarkable that in this large area dykes are quite absent, unless we regard the few diabase outcrops as portions of dykes.

Absence of dyke rocks.

VII.—ECONOMIC GEOLOGY.

Nothing of special economic value has been discovered in the rocks of the area described in this report.

Iron.

Iron is manufactured locally in scores of villages scattered over the country occupied by the crystalline schists, though I have no knowledge of such occurrences outside that group of rocks. The ore varies from magnetite quartz-schist (specimen $\frac{14}{508}$) near Modpodor, concretionary limonite near Malsama, to compact limonite near Bagchua (specimens $\frac{14}{487}$ and $\frac{14}{516}$). There are no extensive workings, and I believe that the limonites are only superficial formations from which no great quantity could be obtained. Outcrops of quartz magnetite schist, however, belong to a different class, for in them the ore is a member of the crystalline schists, and in them larger quantities possibly, and of richer grade may be found by exploration. At present, however, in any case the great distance from any means of easy transport renders these ores comparatively valueless, and an industry of modern proportions is impossible. Under careful conservation the forests in the vicinity of Modpodor and Ramagiri are capable of furnishing an abundance of charcoal for iron working.

Iron smelting in Jeypore.

The method pursued by the villagers in manufacturing iron is very simple. Charcoal and iron ore, broken to about the size of walnuts, are mingled, and smelted in an upright cylindrical clay furnace about 8 inches in diameter and 30 inches in height. The furnaces are built into the wall of a pit, and supplied by means of the common bellows with blast from below. The iron produced appears to be of good quality, as it is used for making sickles, ploughshares, axes, and, in fact, almost all iron implements used by the villagers.

Potstone.

Potstone occurs to the south-west of Jeypore, towards Noaput and Outagaon, and is being used to a small extent for building purposes and for the manufacture of idols. It is much more abundant and of slightly better quality south of Kolar, though in none of the outcrops examined was the rock of a very high quality.

Limestone.

The limestone along the Kolab near Araguda, and possibly some of the limestone in the vicinity of Kondajori, could be used for the manufacture of lime, while some of the mottled dolomitic limestone from the latter locality are very pretty as ornamental stones when polished.

Reference has already been made to the quartzose rocks along the boundary between the Cuddapahs and the crystalline schists. Some of these rocks so closely resemble auriferous rocks of the Dharwar system, as to be worth prospecting. It is well known that in certain places along the Kolab the sands yield small quantities of gold on washing.

Gold (?)

Notes on the Relationship between *the* Productus limestone *and the* Ceratite formation *of the* Salt Range, *by* FRITZ NOETLING, Ph. D. (Berlin), F. G. S., *Palæontologist, Geological Survey of India.*

I.—INTRODUCTION.

Ever since Dr. Fleming's discovery of a rich fauna in beds which he called "Productus limestone" the latter have excited the greatest interest amongst geologists. Dr. Fleming's collection was sent to Europe, and owing to the frequency of *Producti* the strata containing this fauna were pronounced to belong to the carboniferous system, and were correlated with the mountain limestone series. But not only did Dr. Fleming collect palæozoic brachiopods, but also a considerable number of ammonites, which belonged exclusively to the group of *Ceratitidæ*; his statement that they occurred together with the *Producti* was discredited and considered to be based on wrong observations. Yet Dr. Fleming's statement was by no means such an erroneous one, as it was generally believed to be, and if the evidence had been considered not so much from the standpoint of the geological dogma, our views regarding the age of the productus limestone and the ceratite formation would have been altered long ago.

On the authority of Dr. Verneuil, Davidson, Dr. Koninck, and Murchison, the productus limestone was pronounced to be of carboniferous age, and this view Mr. Wynne adopted in his excellent memoir on the Salt Range; he considered the productus limestone to be carboniferous and the "ceratite formation" as triassic. This is to be regretted, as Mr. Wynne himself noticed the very gradual passage from the productus beds into the ceratite formation, and it will be admitted that if we assume the productus limestone to be carboniferous, it is *primâ facie* impossible that the ceratite formation can represent the triassic system, and if we consider the ceratite formation to be triassic, the beds underlying the same cannot possibly represent the mountain limestone, considering the gradual passage which exists between the two series of beds.

The late Professor Waagen was originally inclined to believe in the carboniferous age of the productus limestone,[1] but as the determination of the fossils progressed, he felt himself obliged to change his views considerably, and after various alterations he finally decided that the productus limestone plus the lavender clay and speckled sandstone represented the permo-carboniferous and the whole of the permian system.[2]

In his subsequent publications dealing with the ceratite formation, Professor Waagen stated positively that there existed a break between the ceratite formation and the productus limestone and that the equivalents of the *Otoceras beds* of the Himalayas were absent in the Salt Range.

When I visited the Salt Range for the first time in January 1894, I had an opportunity of observing the fine section in the Chideru ravine. The strata exposed range from the lavender clay up to the upper ceratite limestone, though owing to a local fault, the lower productus limestone could not be observed. It is sufficient for our purposes to say, that an uninterrupted sequence of beds from the middle productus limestone (Kalabagh beds, Waagen), up to the upper ceratite limestone (zone of *Stephanites superbus*, Waagen), could be observed. I noticed at once that there existed a gradual passage between beds which owing to the occurrence of *Productus indicus* unquestionably belonged to the permian, overlaid by beds which contained numerous though ill-preserved specimens of *ceratites* species. Unfortunately I had not sufficient time to study this section in detail and my notes were put aside until a more favourable opportunity should arrive.

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[1] Mem. Geolog. Survey of India, Vol. IX., p. 353.

[2] Salt Range Fossils. Geological Results, p. 241.

When returning from Baluchistan in November 1898, I paid another hurried visit to Chideru in order to verify my previous observations; but before publishing the results, it was deemed necessary that I should devote more time to the study of the productus limestone and the triassic beds at other localities in the Salt Range. I was consequently deputed during the field season 1899-1900, to the Salt Range, where I visited and carefully examined the sections near Virgal, Warcha and Chideru. Although there are still many other localities which could not be visited, the study of the above sections has proved with absolute certainty the existence of a gradual passage between productus limestone and ceratite formation. This is no new discovery so to speak, because Mr. Wynne had already noticed the same, but my observations proved enough to show that Waagen's belief in an unconformity between the productus limestone and the ceratite formation, which he has distinctly set forth[1] in the now famous paper on the sub-division of the triassic system is absolutely erroneous. But more than that, I succeeded in discovering a species closely related to *Otoceras*, not as I expected, below the lower ceratite limestone, but actually right in the middle of the ceratite marl, thus not only proving that *Otoceras beds* exist in the Salt Range, as I have always maintained on stratigraphical grounds, but that the ceratite marls have to be considered to be the equivalent of the *Otoceras* beds.

In addition to the above I discovered that the main layer of *Xenodiscus carbonarius*, Waagen,[2] is considerably lower down in the sequence than believed to be by Waagen. A few more observations regarding the boulder bed, speckled sandstone and the lower productus limestone enabled me to trace satisfactorily the relations between the glacial palæo-dyas and the marine neo-dyas.

It would be out of place to go into details in a preliminary note, and I reserve to myself the right of being more explicit in a subsequent paper. It will be perfectly sufficient if I give here the section near Chideru, and also set forth the sub-division of the productus limestone and ceratite formation as adopted by me on the strength of my recent observations.

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[1] Entwurf einer Gliederung d. pelag. Sedimente d. Trias Systems. Sitzungsber d. K. K Akademie d. Wissensch, 1895, Vol. CIV, Pt. 1, p. 1271 ff.

[2] In order not to cause mistakes I retain Waagen's name, though in many cases I do not agree with him as to the correctness of the determinations.

2.—SECTION IN THE CHIDERU RAVINE.

The small village of Chideru is situated in the western part of the Salt Range, about 12 miles north of Wanbachran railway station, and therefore easily accessible during all times of the year. To north-east of the village, which is right at the foot of the hills, a tortuous and wild glen cuts through a low range, which is succeeded by a fairly broad valley; it is here where the passage between productus limestone and ceratite formation can best be seen.

At the foot of the hills a detached mass of middle productus limestone, dipping at a high angle towards west, and disappearing under the alluvial deposits will be met with. It is much shattered and separated by a small fault from a purple coloured sandstone. The latter is followed by the lavender clay the beds of which form a distinct flexure. Above the lavender clay follows a series of beds, the exact nature of which could not be ascertained as they are covered with debris from the middle productus limestone. Then follows the middle productus limestone, obviously a slipped mass, which is separated from the main range by a fault. In the main range we first have a slope, covered with talus, probably hiding the lower part of the middle productus limestone, then the middle productus limestone forming a precipice facing west, and dipping about 50°-60° north-east. Then follows in an uninterrupted series, the upper productus limestone, and the ceratite formation, which dips towards the productus limestone on the northern side of the valley, thus proving the existence of another fault. In descending order the section is as follows :—

	Ft.	in.
26. Whitish calcareous sandstone	12	0
25. Stachella sandstone	5	0
24. Olive coloured, thin bedded limestone, alternating with . marls of the same colour (Zone of *Stephanites superbus*).	50	0
23. Olive coloured, somewhat brownish, rather hard calcareous sandstone, with numerous specimens of *Flemingites flemingianus*, Waagen, and *Aspidites superbus*, Waagen (Zone of *Flemingites flemingianus*).	10	0

	Ft.	in.
22. Dark bluish green marls having a few thin layers of limestone imbedded. Fossil very common, the following Zones could be distinguished— Zone of *Koninckites volutus*, Waagen. Zone of *Prionolobus rotuntatus*, Waagen. Zone of *Celtites* spec.	100	0
21. Dark brown, hard and flaggy limestone with numerous ill-preserved fragments of *Ceratites*	3	0
20. Green marl	2	0
19. Dark brown, hard and flaggy limestone with numerous ill-preserved fragments of *Ceratites*	5	0
18. Light brown, thinly-bedded sandstone separated by argillaceous layers	2	6
17. Limestone of rusty brown colour, hard and ringing under the hammer; indistinct traces of *ammonoidea* . .	0	4
16. Light brown, thinly-bedded sandstone separated by argillaceous layers	3	0
15. Hard, dark, calcareous sandstone, full of small fragments of shells, apparently *Bellerophon* (?) or *Stachella.*	0	6
14. Shaly calcareous sandstone of brown colour, apparently unfossiliferous	3	6
13. Hard, dark brown, calcareous sandstone separated by argillaceous layers, full of fragments of shells (*Bellerophon* (?) or *Stachella*).	4	3
12. Brown clay	0	4
11. Thickly-bedded rather soft sandstone of pale yellow colour forming a very continuous bed, subdivided by a few argillaceous layers only. Unfossiliferous.	5	6
10 Light brown clay, with strings of calcareous sandstone and gypsum, unfossiliferous	12	0
9. Hard limestone of light brown colour, full of— *Bellerophon impressus*, Waagen . . *Schizodus pinguis*, Waagen.	1	6
8. Soft yellowish sandstone, unfossiliferous	4	0
7. Soft sandstone of light yellow colour, full of large specimens of *Productus indicus*, Waagen	9	0
6. Soft sandstone of dark brown colour containing numerous specimens of— *Productus indicus*, Waagen, *Oldhamina decipiens*, Koninck, *Dentalium herculaneum*, Waagen .	25	0
5. Soft rusty brown sandstone, with hard calcareous layers, full of— *Derbyia hemispherica*, Waagen . .	120	0

	Ft.	in.
4. Hard, brown sandstone in thick layers apparently unfossiliferous	65	0
3. Yellow sandstone with hard streaks, full of— *Productus indicus*, Waagen, *Productus cora*, d'Orbigny	50	0
2. Greenish clay apparently unfossiliferous	25	0
1. Hard nodular limestone of grey colour, full of fossils, thickness not measured, but representing the typical middle productus limestone.		

If we go through the above section, the single beds of which, as cannot sufficiently be emphasised, pass so gradually into each other, that it is frequently difficult to draw the boundary between the same, we may observe that there cannot be the slightest doubt as to the age of the beds 1, 2 to 9, and 17 to 26.

The beds 17 to 26 represent the ceratite formation in its horizons as distinguished by Wynne, *viz.*:—

	Ft.	in.
25 24 } Upper ceratite limestone and ceratite sandstone 23	77	0
22 Ceratite marls	120	0
21 –17 Lower ceratite limestone	12	10

The beds 2 to 9 unquestionably represent the upper productus limestone. Bed 1 represents the middle productus limestone.

There remain therefore only beds 16 to 10 having an aggregate thickness of 29′ 1″, the stratigraphical position of which remains somewhat uncertain for the present, owing to the absence of distinct fossils. The lithological character of the beds from Nos. 15 to 10 is however such that I would unquestionably include them in the upper productus limestone as it is more in accordance with the lower than with the upper beds. It is extremely unfortunate that the fragments of the shells are so minute, that it is impossible to say whether they belonged to the genus *Bellerophon* or *Stachella.*

The above section proves unquestionably the gradual passage between the productus limestone and the ceratite formation; but in order to understand the conditions more clearly we may summarise the lithological facts in the following way:

In the middle productus limestone hard, white limestone in thick beds prevails. This is gradually replaced by soft limestone of brownish colour separated by argillaceous beds of considerable thickness, in various tinges of yellow or brown. The colour of the shales gradually darkens to bluish green, as can be particularly well seen near Vergal; and the limestone bands become more subordinate. The lower part of the ceratite marl is dark blue, but the colour gradually gets lighter, at the same time thin beds of limestone, argillaceous limestone, even sandstone, make their appearance, and towards the close of the series whitish beds appear.

Whatever view may eventually be held with regard to the ceratite formation I cannot sufficiently emphasise the fact that stratigraphically it belongs to the productus limestone series, from which it cannot possibly be separated, and any attempt at a sub-division must absolutely and solely be based on palæontological grounds.

3.—NOTES ON THE PRODUCTUS LIMESTONE.

Further east of Chideru a very fine section from the middle productus limestone up to the base of the ceratite formation can be seen. The beds are here particularly rich in fossils. It was at this place that I discovered the main layer of *Xenodiscus carbonarius* which occurs in about the topmost 20 feet of the middle productus limestone together with *Productus indicus.*

Under these circumstances it is no longer admissible to distinguish a separate cephalopod bed within Waagen's meaning, in the upper productus limestone, particularly if we keep in mind that the cephalopods in this group are extremely rare.

Unfortunately I had no opportunities of studying the lower productus limestone in greater detail, because it is nowhere well developed in the localities which I have visited. I have, however, been able to ascertain, that if developed together at the same place, the glacial boulder bed is always the oldest in the series; this is overlaid by the speckled sandstone beds, which in their turn are followed by the lavender clay; the lavender clay passes gradually into the lower productus limestone.

So far only very few fossils have been found in the lower part of the series, namely, bivalve casts and *Conularia* nodules.

The productus limestone fauna makes its appearance very suddenly, and in the lowest fossiliferous bed which I could discover the same fauna prevails as in higher beds.

The following is the sub-division of the permian in the Salt Range according to my interpretation :—

Trias.		Baktrian.	Upper ceratite limestone.		Zone of *Stephanites superbus,* Waagen.
			Ceratite sandstone.		Zone of *Flemingites flemingianus,* Waagen.
			Ceratite marls.	Otoceras beds.	Zone of *Koninckites volutus,* Waagen.
					Zone of *Prionolobus rotuntatus.*
			Lower ceratite limestone.		Zone of *Celtites spec.*
Marine Neo-Dyas.	Zechstein.	Sindian.	Upper productus limestone.		Zone of *Euphemus indicus,* Waagen.
					Zone of *Derbyia hemisphærica,* Waagen.
					Zone of *Productus lineatus,* Waagen.
			Middle productus limestone.		Zone of *Xenodiscus carbonarius,* Waagen.
					Zone of *Lyttonia nobilis,* Waagen.
Marine Palæo-Dyas.					Zone of *Fusulina cattaensis,* Waagen.
			Lower productus limestone.		Zone of *Spirifer marcoui,* Waagen.
Glacial Palæo-Dyas.	Roth-liegendes.	Dravidian.	Speckled sandstone.		Lavender clay, unfossiliferous.
				Specked. sandstone.	Zone of *Conularia lævigata,* Waagen.
					Zone of *Eurydisma globosum,* Waagen.
					Boulder-bed.

Progress report on the Survey of Spiti and adjoining areas, *by* H. H. Hayden, B.A., B.E., *Officiating Deputy Superintendent, Geological Survey of India.*

In order to resume the work begun in the summer of 1898, I returned to Spiti in May of last year. I was accompanied on this occasion by my colleague, Dr. A. von Krafft, to whose valuable assistance must be attributed much of the progress made during the past season.

A short summary of the results obtained in 1898 has already been published in the last "General Report, " 1898-99,[1] from which it will be seen that special attention was paid to the older beds of Spiti, including the palæozoic group and the lower trias. The chief object in view, therefore, during the past season was to examine, in as great detail as was possible in the time at our disposal, the remainder of the mesozoic group, and also to complete the geological map of Spiti and carry the survey, as far as possible, into the adjoining areas. Although much of this has been accomplished, and the results obtained have proved to be more comprehensive and more important than we had expected, yet a few points still remain doubtful and it is desirable, before publishing an account having any pretensions to completeness, that these should be cleared up by a short visit to certain localities, which owing to want of time have hitherto received less attention than they deserve.

The earlier part of the past season was devoted to an examination of the whole sequence of rocks found in the valleys of the Pin and Parahio rivers. I then left Spiti and crossed the Mánirang pass into Bashahr, where I completed the map of the north-western portion of that state, working round eventually to the junction of the Spiti and Pára rivers, whence I crossed a portion of Hundes, striking British territory again at Chágya Sumdo in Rupshu. I thence worked up to Tso[2] Morari and mapped as much as was possible of the portions of Rupshu adjoining Spiti, returning to Kibber *via* the Párang La.[3] In the meantime Dr. Krafft, who had remained in Spiti, had been engaged in mapping some of the north-eastern parts of that area, and in working out in detail the whole of the mesozoic group from lower trias to cretaceous: he then joined me at Kibber and we worked out *via* Losar and the Hamta pass to Kulu.

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[1] See pages 11 to 22 and 46 to 50.

[2] Tso=lake.

[3] La=pass.

SPITI AND BASHAHR.

Palæozoic Group.

Haimanta system.—There is little to add to the notes made in 1898 with reference to this system: we have still failed to find in Spiti any trace of the lowest sub-division, as seen in the eastern Himalayas, *viz.*, that characterised by the prevalence of conglomerates.[1]

Middle haimantas.

The middle division, as seen in Spiti, was described in the previous summary. In Bashahr it is exposed in the Thanam and Sutlej valleys and consists in the former locality of quartzites and slates with beds of grit towards the top.

In the Sutlej valley below Hango the rocks of this division have been much altered by intrusive granite and are represented chiefly by quartz schists and garnetiferous mica schists with Kyanite.

Upper haimantas.

The upper haimantas ("red quartz shales" of Mr. Griesbach[1]) are well developed in Bashahr, and are more characteristic than in Spiti. They consist of dark blue, black and green magnesium slates, weathering bright red and yellow, with subordinate bands of quartz schist and black carbonaceous shale,—the whole having a thickness of not less than 1,000 feet.

Upper cambrian "trilobite beds."

It has already been recorded (see previous report) that in the valley of the Parahio river in Spiti, these "red quartz shales" are overlain by a series of quartzites and slates, with thin bands of reddish brown dolomite, and in these beds upper cambrian *trilobites* were found in 1898. Wherever the upper haimantas have been found, careful search has been made for these "trilobite beds," but except in the Pin valley near Muth, fossils have not been discovered in any new locality.

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[1] Mem., G. S. I., vol. XXIII, p. 51.

Cambro-silurian unconformity.

A detailed examination of the original section in the Parahio valley proves that an important unconformity exists between this series and the overlying silurian grits and quartzites. The highest member of the upper cambrian is a thick bed of reddish-brown dolomite, which is apparently always overlain by one or more bands of conglomerate. The lowest of these bands is made up of fragments of the dolomite, and varies in thickness from about five feet to nearly two hundred; in the former case it lies on an eroded surface of the dolomite, but in the latter, it completely replaces the dolomite, and rests unconformably on the shales and quartzites of the "trilobite beds."

The upper conglomerate is composed of fragments of quartzite probably derived from the upper and middle haimantas, and has been found in every section examined, whereas the lower or dolomite conglomerate is occasionally absent, as is the case in the Thanam valley. The boundary between the upper cambrian and silurian systems should probably be taken at the base of these conglomerates, and not, as was originally suggested, at the base of the reddish-brown dolomite: this assumption, however, is based merely on the intimate lithological connection between the dolomite and the underlying beds, for no fossils of lower silurian age have yet been found in Spiti.

Lower silurian?

Silurian.—It is possible that no lower silurian rocks occur in this area, for there is no trace of the "lower silurian *coral* limestone" found by Mr. Griesbach in the Niti sections, its place being apparently taken in Spiti by the upper cambrian trilobite beds and conglomerates (in the Parahio valley), and by the conglomerates, with portions of the trilobite beds, in the Pin valley and other localities.

Throughout Spiti the higher conglomerate passes up gradually into the great system of red grits and quartzites referred by Mr. Griesbach to the upper silurian. In Spiti no trace of fossils has been found in this series, but it is overlain by some 650 feet of shales, and limestones containing an undoubted upper silurian fauna, and its age is therefore probably either middle or lower silurian.

Upper silurian.

The upper silurian rocks were briefly described in my previous report. Further collections made, during the past season, include several specimens of *Calymene* sp., numerous *brachiopods* and very fine specimens of

Halysites catenularia, Lmck., and the assumption of an upper silurian age for these beds has now been confirmed.

Devonian ?

The grey coral limestone containing *Halysites catenularia* is overlain by about 100 ft. of hard, grey, siliceous limestone, weathering brownish-red (—"red crinoid limestone," Griesbach). A few fossils have been obtained from this limestone, but they are not sufficiently well-preserved to throw much light on the question of the age of the rock: its position, however, —immediately overlying upper silurian beds—would indicate a devonian age. But further search in the sections near Lio in Bashahr would probably result in the discovery of better fossils.

The red crinoid limestone passes up gradually into a reddish quartzite, which in turn shades off into the white (Muth) quartzite.

Carboniferous and permian.—In the section near Muth—"southern facies" (Stoliczka)—this quartzite is overlain by a few hundred feet of limestone which is separated from the overlying permian sandstone and productus shales by a thin bed of conglomerate, while in the sections in lower Spiti (the "eastern facies"), the productus shales and their associated sandstone (or sandy limestone) are underlain by conglomerates which pass down into several thousand feet of alternating shales and quartzites, and neither the white (Muth) quartzite, nor the overlying limestone, are seen: it was, therefore, supposed by previous observers (Stoliczka and Griesbach) that an unconformity existed between the carboniferous limestones and the productus shales. This unconformity—which occurs at the base, not of the productus shales but of the permian calcareous sandstone, which everywhere immediately underlies the productus shales—has now been traced throughout the whole length of Spiti and northern Bashahr. In Spiti the characteristic facies of the upper palæozoic is the southern of Stoliczka, *viz.*, the white (Muth) quartzite overlain by a relatively small thickness of grey limestone, upon which the permian sandstone rests unconformably. At the head of the Thanam valley, the limestone gradually disappears and the sandstone lies on the white quartzite, which, however, as the outcrop is followed from west to east, also dies out, and so on with the underlying beds until the permian sandstone is found resting with apparent conformity on the red silurian quartzite. Higher beds then gradually re-appear, and at the Hangrang pass, between Sungnam and Hango, the sandstone rests on the lower beds of the upper silurian limestones. North of Hango the white (Muth) quartzite is again seen in small patches, gradually increasing in thickness, till above Lio in the valley of the Lipak river, what appears to be a complete section of the carboniferous and permian beds is found. The section up to the top of the Muth quartzite is perfectly normal; these follow in *ascending* order :—

(*a*) grey limestone,
(*b*) alternating beds of limestone, shale and quartzite, with a thin band of conglomerate,
(*c*) thick mass of hard, dark limestone, with some flaggy sandstones and slates,
(*d*) shales and quartzites (the "eastern facies"),
(*e*) conglomerates and grits passing up into calcareous sandstone (permian),
(*f*) productus shales.

This is probably the most complete section of carboniferous and permian beds yet known in the Himalayas, and the total thickness from the base of the Muth quartzite to the base of the productus shales is certainly not less than 5,000 feet.

Grey limestone: ? upper carboniferous.

Fossils have been found in *a*, *c*, *d*, and *e*. In the lowest bed (*a*),—"upper carboniferous limestone (8*a*)" of Griesbach [1]—*brachiopods* are common, but as a rule badly preserved: they include the genera *Productus*, *Athyris*, *Dielasma Derbyia* and *Syringothyris*, the last-named being the commonest, and being represented by at least two species, which, however, owing to the bad state of preservation of the specimens cannot be identified with certainty. One species, however, is indistinguishable from a form described by Dr. Diener [2] as *S. cuspidata*, Mart. Diener's specimen was collected by Stoliczka near Kuling in Spiti, where this limestone is exposed; the specimen, however, would seem too fragmentary to warrant specific identification.

? Permian.

Fossils occur at several horizons in the sub-division (*c*) These include species of *Syringothyris*, *Spiriferina*, *Rhynchonella* (cf. *pleurodon*, Phill.), *Discina*,

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[1] Mem., G. S. I., Vol. XXIII, p. 216.

[2] Pal. Indica, ser. XV, Vol. I, pt. 2, p. 76. Dr. Diener infers that the specimen was collected from a lower carboniferous limestone which, in Niti, occur below the white (Muth) quartzite; this bed, however, is not exposed at Kuling, the lowest member of the section being the white quartzite. The matrix, too, is indistinguishable from that of specimens collected by us in Spiti in the *upper* limestone (8*a*). His inference of a lower carboniferous age is therefore hardly justified.

Athyris, Productus, Chonetes, Derbyia. As a rule the specimens are too poor to be identified specifically, but they strongly resemble forms from the productus limestone of the Salt Range and are probably of permian age. A pygidium of ***Phillipsia,*** closely resembling ***P. cliffordi,*** Woodw., was also found in these beds.

Probable representatives of the "Productus Limestone."

In the time at my disposal it was possible to make only a superficial examination of this section, but the resemblance between the series of quartzites and limestones and the productus limestone series as seen on the North-West Frontier is very striking, and it is probable that a detailed investigation would throw considerable light on the true relation and extent of the carboniferous and permian systems of the Himalayas.

"Fenestella shales."

The overlying shales and quartzites attain a thickness of about 4,000 feet, but are rarely fossiliferous. Near Po, however, some of the higher shale bands contain large numbers of ***Bryozoa*** chiefly ***Fenestella,*** and these beds probably represent the Barus or Zewán beds of Kashmir. ***Brachiopods*** also occur, but they are very badly preserved.

Conglomerates.

Permian sandstone.

These shales and quartzites are overlain by grits and conglomerates of varying thickness, passing up into a coarse calcareous sandstone or sandy limestone. Fossils, chiefly ***Producti,*** occur in the grits, but they are badly preserved as a rule. The calcareous sandstone, however, contains numerous ***brachiopods,*** among which the following forms have been recognised:

Spirifer musakheylensis, Dav.
„ cf. ***nitiensis,*** Diener.
Athyris gerardi, Diener.
„ ***subtilita.*** „
Productus purdoni, Dav.
Martinia glabra, Mart.
Dielasma sp.

In Spiti and Bashahr this bed invariably accompanies the productus shales, with which it seems always to be intimately connected. Below it occurs the great unconformity which is so strongly marked in the southern parts of Spiti and in the Thanam valley.

Correlation of conglomerate of Po with Blaini beds probably incorrect.

The underlying conglomerates, which are well seen near Po and, Dankhar, were supposed by Mr. Oldham, who visited these localities, to be of glacial origin, and it was suggested that they might be homotaxial with the boulder slates of the Blaini series.[1] These again have been correlated with the Talchir and Salt Range boulder-beds.[2] My doubts as to the correctness of the former correlation on lithological grounds, have already been stated.[3] These doubts have been considerably strengthened by the discovery of the limestones and quartzites of the Lipak river; for if, as seems probable, they are the equivalents of the productus limestone of the Salt Range, then the *overlying* conglomerates must be considerably younger than the Salt Range boulder bed. This emphasises the necessity for a more detailed investigation of the Lipak limestones.

At the north-west end of Spiti also, at Losar, the carboniferous-permian beds are almost, if not quite, as thick as at Lio; but at the time of our visit the country was almost completely covered with snow and it was impossible to examine the beds in any detail. It is evident, however, that throughout the greater part of Spiti these systems are comparatively thin, but, towards both the north-western and south-eastern boundaries, they suddenly increase in thickness.

Productus shales.

Further collections of ammonites have been made from the upper part of the productus shales, but they have not yet been worked out.

Classification of the palæozoic systems.

The following table contains a rough classification of the palæozoic systems of Spiti and B ashahr, referred as nearly as is at present possible, to their probable European equivalents.

Black shales=" Productus shales."	With *Xenodiscus carbonarius*, Waag., *Cyclolobus* cf. *oldhami*, Waag., and other cephalopoda in the upper part, and the usual *brachiopoda* of the "productus shales" in the lower.	Carboniferous and permian.

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[1] Records, G. S. I., Vol. XXI, p. 151.

[2] Manual of the Geology of India, 2nd Ed., pp. 135, 206.

[3] General Report, G. S. I., 1898-99, p. 48.

Calcareous sandstone or sandy limestone, underlain by grits and conglomerates.	With *Spirifer musakheylensis*, Dav., *Athyris gerardi*, Diener, *Athyris subtilita*, Diener, *Productus purdoni*, Dav., *Martinia glabra*, Mart., *Dielasma* sp.	Carboniferous and permian.
Alternating beds of shale and quartzite. Limestones, slates and quartzites.	With numerous *bryozoa* and *brachiopoda*. With *Phillipsia* cf. *cliffordi*, Woodw., *Syringothyris* sp., *Spiriferina* sp., *Rhynchonella* cf. *pleurodon*, Phill., *Discina* sp., *Athyris* sp., *Productus* sp., *Chonetes* sp. and *Derbyia* sp.	
Grey limestone, often oolitic and crinoidal.	With *Productus*, *Athyris*, *Dielasma*, *Syringothyris* (the last named genus very common).	
White quartzite = " Muth quartzite " (Stoliczka).	Apparently unfossiliferous . .	? Carboniferous.
Grey siliceous limestone, weathering brownish red = " Red crinoid limestone " (Griesbach).	With fragments of *crinoids* and *brachiopods*.	? Devonian.
Limestones, marls and slates.	With *Halysites catenularia*, Lmck., and other corals in the upper beds and *Calymene* sp., *Strophomena* sp., in the lower.	Upper silurian.
Red gritty quartzite, underlain by conglomerate.	Apparently unfossiliferous . .	? Lower silurian.
Slates and quartzites, with a few bands of dolomite.	With upper cambrian *trilobites* .	Upper cambrian.
Red quartz-schists, slates and carbonaceous shales.	......	Upper haimanta.
Quartzites and slates .	......	Middle haimanta.

MESOZOIC GROUP.

Trias.—During the season of 1898 work was confined chiefly to the lower trias including the "Otoceras beds," "Subrobustus beds" and Muschelkalk, from all of which collections were made. These collections were examined by Dr. A. von Krafft (see "General Report," 1898-99, p. 11) and were found to include some new and interesting material. During the past season considerable additions—chiefly of new or rare forms—have been made to those collections, but attention was chiefly directed to the upper trias, from which collections were made while the whole sequence of beds was examined, so far as was possible in the time at our disposal. During the past few months these collections have been examined by Dr. Krafft, and the following notes are based chiefly on the results of his investigations, of which a fuller account will be found in Dr. von Krafft's paper in this year's "General Report." Most of the upper triassic horizons known in the eastern sections of the Himalayas have been recognised in Spiti, where, however, the fossils contained in them are often small in number and badly preserved: but some compensation for this is found in the existence in Spiti of other horizons rich in fossils, hitherto unrecorded from the Himalayas.

Lower trias. "Otoceras beds."

The productus shales are overlain by about six feet of black limestone and shale—the "Otoceras beds" of Niti. *Otoceras* is rare, the most characteristic genera being *Ophiceras* in the lower layers and *Meekoceras* in the upper.

This bed is overlain by grey, thin-bedded earthy limestones, alternating with narrow bands of shale. These represent the "subrobustus beds" (Diener) of the eastern sections. This term, however, is not applicable to the Spiti area.

These are overlain by a thick bed (60 ft.—90 ft.) of grey nodular limestone, in which fossils are very rare and, with the exception of one form (*Nautilus* ex. aff. *N. palladii*, Mojs.), too badly preserved to be identified.

Muschelkalk.

The next series—muschelkalk—consists of grey concretionary limestone in beds about one foot thick, separated by thin bands of shale. The lowest bed contains lower muschelkalk forms together with *Ceratites subrobustus*, E. von Mojs.

Separated from this by a thin parting of shale is another band of limestone containing numerous brachiopods, the commonest being *Spiriferina stracheyi*, Salt. This is overlain by the remainder of the muschelkalk with the usual fossils, *viz.*, *Ptychites gerardi*, Blanf., *Ptychites rugifer*, Oppel, etc.

Ladinic Stage well represented.

The muschelkalk is overlain by a series of calcareous shales with thin bands of limestone, containing several species of ammonites as well as large numbers of *Daonella indica*, Bitt. and *D. lommeli*, Wiss. The prevalence of this characteristic ladinic species is very interesting, and it would seem that that stage is amply represented in Spiti and includes a considerable thickness of beds hitherto supposed to be of carnic age. The hiatus said to exist in the eastern sections between the muschelkalk and the upper carnic is therefore probably only local.

These "daonella shales" pass up gradually into a series of dark splintery and flaggy limestones with thin bands of shale. *Daonella lommeli*, Wiss., has been found in the lower beds, but in the upper is apparently replaced by species of *Halobia*.

This limestone is overlain by a thick series of light grey calcareous shales with dark limestone bands, containing, as a rule, few fossils. The lowest bed of this series is a dark grey shale full of black cherty concretions containing fossils, chiefly *Trachyceras* (cf. *aonoides*) and *Joannites cymbiformis*, Waag. The overlying shales and limestones contain also species of *Halobia* and *Megalodon*, and a band rich in brachiopods including *Spirifer shalshalensis*, Bitt., and *Rhynchonella lankana*, Bitt. Towards the top, limestones are more numerous, the series gradually becoming one of limestone with subordinate bands of shale. These beds, which contain *Tropites* cf. *Sub-bullato*, v. Hau., and *Clydonautilus griesbachi*, E. v. Mojs., presumably represent the "Tropites limestone" of Kalapani, but the fossils are few and badly preserved.

Above this series is a great mass of hard dolomitic limestone, which has yielded only *Megalodon* and a few *brachiopods* and *lamellibranchs*. It is overlain by sandy limestones, flaggy sandstones and dark micaceous shales. The limestones contain bivalves and ammonites, the latter including *Paratibetites* aff. *tornquisti*, E. v. Mojs., and ? *Hauerites* sp. The sandstones are full of badly-preserved plant remains, and the shales contain numerous concretions containing chiefly *Juvavites* sp., and *Paratibetites tornquisti*, E. v. Mojs., a fauna resembling that of the " Halorites beds " of the eastern sections.

The next bed, which forms a very characteristic horizon in Spiti and Rupshu, consists of a hard grey or white dolomitic limestone full of corals, amongst which a very common form is one resembling *Lithodendron*. Other fossils are rare, but *gastropods* occur in Rupshu and *brachiopods* — including *Spiriferina griesbachi*, Bitt., were found by Dr. Krafft near Lilang. This limestone may be equivalent to the " *Spiriferina griesbachi* beds " of Niti.

Above the main mass of the limestone are thin-bedded earthy limestones containing badly preserved fragments of ammonites.

These beds are overlain by flaggy sandstones and shales, strongly resembling the series immediately underlying the coral limestone. Fossils occur near the top of this series, chiefly in two horizons, the lower of which consists of a band composed entirely of remains of *Monotis salinaria*. The higher horizon lies at the top of the shales, and is very rich in fossils, chiefly *Spiriferina griesbachi*, Bitt., which occurs in enormous numbers. Immediately above this horizon are some bands of limestone containing a large bivalve fauna.

The overlying beds form one of the most constant and characteristic horizons of the upper trias of Spiti, and consist of a series of white and brown quartzites, with subordinate limestone bands. The white quartzite bed can be seen at a distance of several miles running as a thin white band among the darker beds in the high cliffs of the upper trias. With the quartzites are intercalated limestones, amongst which is a characteristic bed containing numerous very large specimens of *Megalodon* sp. This bed is found everywhere, but is specially well marked in the Para valley, north of the Parang La, where a very fine *Megalodon* was obtained. Numerous sections of a bivalve nearly two feet in diameter occur in this bed, and probably represent *Dicerocardium*, but no specimens could be obtained. This is the characteristic horizon in Stoliczka's " Para limestone."

Dachsteinkalk.

Above this quartzite series is a great mass of limestone over 2,000 feet thick, probably representing the uppermost trias, the rhætic, and much of the jurassic (lias to probably middle jurassic). Fossils are rare in the lower part of this limestone.

Jurassic.—About the middle of the series fossils become more numerous and resemble liassic types, among these being a ***Spiriferina*** cf. ***obtusæ***, Opp., which occurs about 900 feet above the base of the series; about 1,000 feet higher up an ammonite almost identical with ***Stephanoceras coronatum*** of the Kelloway was found by Dr. von Krafft, and above this, ***brachiopods*** occur in very large number.

Much of this limestone was included by Dr. Stoliczka in his "lower Tagling limestone," which he believed to be of liassic age; it is probable, however, that the uppermost beds are younger, probably middle jurassic. The ***upper Tagling limestone*** which was said to occur only on the Baralatse range, where he found it on the Tagling and Parang passes, proves to be in reality a lower portion of his lower Tagling limestone, which has been brought by an inversion above the higher beds of the same series, its age being probably liassic. These beds are well seen on the saddle of the Parang La.

Spiti shales.

A few fossils were collected from the Spiti shales, but they are not likely to add to our knowledge of the series, previous collections having been very large.

Gieumal sandstone.

Cretaceous.—The Gieumal sandstone was examined in some detail by Dr. Krafft and many fossils, chiefly bivalves, collected.

Chikkim limestone.

The overlying Chikkim limestone, which, in the neighbourhood of Chikkim, has yielded only ***Foraminiferæ*** similar to those previously collected by Stoliczka, in the Lingti valley, contains also ***Belemnites***.

Chikkim shales.

In spite of careful search no fossils were found in the Chikkim shales.

HUNDES AND RUPSHU.

The route followed from Bashahr to Rupshu lay from Kurig, on the Para river, northwards over the hill-ranges to Parkyo, thence down again to the Para river near Kharak, where the river is with difficulty fordable, thence along the high ranges on the left side of the river, by the small village of Akse, to Chagya Sumdo. The southern portion of the area traversed consists entirely of mesozoic rocks. Just north of Kurig the palæozoic rocks are replaced by lower trias beds, dipping to the north and north-east. These are followed by the upper trias, and, at and near the village of Parkyo, by jurassic beds, with Spiti shales. North and north-west of Parkyo, along the right side of the Para river, the Spiti shales are found on the higher parts of the mountains, much of the great range between Spiti and Hundes being composed of younger mesozoic beds. Near Kharak, only upper trias beds occur, and these continue for many miles to the north, but are gradually replaced by older beds, till, at the boundary between Hundes and Rupshu, palæozoic rocks predominate, the trias being found only in the higher parts of the ranges. To the north of Kharak, just beyond the village of Akse, the rocks begin to show signs of metamorphism, which becomes more and more marked towards the north. The greater part of southern Rupshu is, as stated by Stoliczka, composed of metamorphic schists, which being as a rule completely devoid of any trace of fossils, had not hitherto been assigned to any definite geological period. The recent traverse through Hundes, and the examination of portions of Rupshu hitherto unvisited, has now rendered this possible, and they have been found to include both trias and palæozoic beds. As a rule the whole of the carboniferous, permian and trias systems as far as the base of the upper triassic coral limestone, consist of a series of calcareous or siliceous schists, slates and quartzites. Above the coral limestone the upper trias and succeeding systems, which, however, are found only in the higher ranges, have been comparatively little altered, and can be identified by their fossils. The coral limestone forms a most valuable horizon, and throughout Southern Rupshu consists of a conspicuous white dolomite, in which the characteristic corals occur in abundance. Below this limestone, however, metamorphism has in almost all cases completely obliterated all traces of fossils, but the main characters of the rocks have been sufficiently retained to render possible a correlation of the various systems. This correlation, based at first on lithological grounds, has been borne out by the subsequent discovery of fossils.

Jurassic.

The highest beds seen are the jurassic limestones found on the Parang La, and near Tatang encamping ground in the Para valley: these are underlain by the usual limestones (Dachsteinkalk) followed to the north by the upper trias, with the characteristic coral limestone. Under

Trias.

these are limestones (often calcareous schists) and slates, representing the remainder of the trias; fossils (*Daonella*) have been found in these beds in the Pankpo lungba (lungba=stream), where the Daonella limestones and shales have been identified.

Below the trias in the Para river section, *i.e.*, along the Spiti-Korzok road, hard slates (probably representing the productus shales) contain distorted fossils, chiefly *Productus* sp., and *Spirifer musakheylensis*: below these slates are limestones and calcareous schists, part of which probably represent the calcareous (permian) sandstone, which occurs below the productus shales in Spiti; in the Phirse river these limestones and shales are full of crinoid stems. They are underlain by the characteristic conglomerates, followed by a great series of slates, schists and quartzites, which is well seen along the road between Narbo Sumdo and Korzok. A little to the south of Korzok, the siliceous beds are underlain by calcareous schists and crystalline limestones, as already recorded by Mr. Oldham.[1] Thence to a point about 2½ miles north of Korzok the road skirts the shore of the lake (Tso Moriri) along which the section is composed first of limestones and calc schists as at Korzok, underlain by limestones alternating with slates and quartzite, these in turn being underlain by more limestones. In this lowest series of limestones a bed was found containing remains of corals, strongly resembling a coral band which occurs near the middle of the upper silurian limestones of Spiti and Bashahr.

Below these limestones are slates or schists, gradually becoming garnetiferous, then felspathic, and passing gradually downwards through thin-bedded gneisses into the great system of gneiss and quartz-schist, which forms the precipitous ridge running from the head of Tso Moriri towards the north-west.

There seems therefore little doubt that from the base of the trias down to this gneiss, the above sequence consists of the altered representatives of the permian, carboniferous, and upper silurian systems, as seen in Bashahr and lower Spiti, and it is possible that the underlying gneiss may represent the great quartzite series which occurs eleswhere below the upper silurian limestones and shales. Seen from a distance, the gneiss, which forms bold cliffs of a hard, apparently well-bedded rock, bears a striking resemblance to the silurian quartzite, but on closer examination it is found to consist of alternating beds of gneiss and partly schist.

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[1] Rec., G. S. I., vol. XXI.

The gneiss, which is composed of quartz, orthoclase, muscovite and schörl, with very fine "*augen*" structure, has a distinctly bedded appearance, the "beds" which are about two feet thick being perfectly even and continuous, while the intercalated bands of quartz schist intensify the sedimentary appearance of the system. Unfortunately the time available did not allow of anything more than a cursory examination, and the base of the series not being exposed, it is impossible to refer it at present to any known system. It is probable that a continuation of the survey towards the north-west would throw some light on the question, as in that direction the beds appear to be less metamorphosed than in the neighbourhood of Tso Moriri, where intrusions of granite and of basic igneous rock are numerous.

IGNEOUS ROCKS.

Granite.

From the great granite mass at the head of the Sutlej valley in Kanaur, an arm runs almost continuously through the mountains lying to the north of the Para river in Hundes, into, and through Hanle and southern Rupshu. The beds traversed are partly of triassic, chiefly of carboniferous age. In southern Rupshu the essential minerals of the granite are quartz. orthoclase, biotite and a little muscovite, and the rock exactly resembles the granite of the Chandra valley between Spiti and Kulu, where, however, garnet occurs as an accessory mineral, and bands of coarse pegmatite with muscovite are very common.

Basic intrusion.

Basic rocks are numerous in Rupshu, where they are found intruded into the trias and carboniferous beds, and also into the Tso Moriri gneiss. They appear on a cursory examination to fall into two groups, a garnetiferous and a non-garnetiferous. The former are found in the gneiss, while the latter—chiefly composed of basalts and dolerites—occur among the trias and carboniferous beds. Want of time unfortunately precluded more than a very rapid examination of these rocks, and it is impossible to say whether the two groups have each a distinct origin; but the fact that all the intrusive rocks found in the gneiss contained garnets, while no trace of garnets could be found among the intrusives occurring in the trias and carboniferous beds, make it seem possible that the difference may be due to the rock into which they have been intruded. But the evidence being merely negative no conclusion can safely be drawn.

ECONOMIC MINERALS.

Gypsum.—In addition to the localities already recorded by Mallet, gypsum occurs in large quantities in the upper beds of the limestone series on the ridge between the Lipak and Yulang (Yalung) rivers in Bashahr, and in the upper Gyundi valley in Spiti.

Gold.—At Chagya Sumdo on the Rupshu-Hundes border several pits have been sunk in the sub-recent deposits on the left bank of the Para river. Alluvial gold is said to have been obtained here in small quantities by the Tibetans, but the mines have not been worked for some fifteen or sixteen years. I washed a few pounds of material from the neighbouring stream but found no gold.

Stratigraphical notes *on the* Mesozoic rocks *of* Spiti, *by* DR. A. von KRAFFT, *Geological Survey of India.*

The following is a preliminary account of the triassic rocks of Spiti. It embodies the stratigraphical results obtained by Mr. Hayden and myself during the summer of 1899, as well as the results of an examination of our collections. The largest number of the lower trias cephalopoda, recently collected in Spiti, has been described and worked out in full detail. The rest of the collections were examined as far as they appeared to be of stratigraphical importance.

The trias has been studied by me especially in the sections near Lilang on the Lingti river.

Lower trias. Sequence at Lilang.

The lower-triassic sequence seen about 1½ miles north of Lilang on the left bank of the Lingti river, is as follows:—

(1) The Otoceras beds begin with a rusty brown, ferruginous layer of 1 to 5 inches in thickness, which has yielded only one badly preserved specimen, probably belonging to the genus

Ophiceras.

Then follows a sandy brown weathering limestone of 1 foot 7 inches, without fossils, overlaid by

(2) a limestone bed of 1 foot 5 inches, which most likely represents the "Main layer of *Otoceras woodwardi*" of the Shalshal cliff section (Pal. Indica, ser. XV, vol. II, pt. 1, p. 3). This bed is full of *Ophiceras sakuntala,* Dien., and other species of *Ophiceras;* it further contains

Meckoceras varaha, Dien.
„ *cf. boreale,* Dien.
„ nova sp. (two different species).
Danubites radians, Waag. var.
Pseudomonotis griesbachi, Bitt.

Otoceras has not been found in this bed at Lilang. It appears to be very rare in Spiti.

(3) Then follows a series of thin, black, concretionary limestone beds, alternating with thin shaly layers, together 3 feet thick. The prominent genus in these beds is *Meekoceras.* The species represented are—

Meekoceras varaha, Dien.
„ *cf. Hodgsoni,* Dien.

as well as seven new species, one of which is already present in bed 2 (see above). Of the six other new *Meekoceras,* one represents the group of smooth forms classified by Prof. Waagen with his genus *Gyronites,* although it is not perfectly identical with any of the Salt Range species. Another new species is allied—although not very closely—to "*Aspidites*" *discus,* Waag., from the middle ceratite sandstone. A third is no doubt the direct ancestor of "*Aspidites*" *superbus*, Waag., occurring in the upper division of the lower trias of the Himalayas ("Subrobustus beds," Diener[1]) and in the upper region of the ceratite sandstones of the Salt Range.

As to the rest of the new species of *Meekoceras* no affinities to described forms can be recognized.

Besides these new species there must be mentioned a form very close allied to the Arctic "*Xenodiscus schmidti*, E. v. Mojs. (Arktische Triasfaunen, pl. xi, fig. 11) and a form most probably identical with *Meekoceras pulchrum*, Waag., from the ceratite marls of the Salt Range. There have further to be recorded—

Proptychites ammonoides, Waag.
„ *sp. aff. latifimbriato*, Waag.
„ *Markhami*, Dien.
Clypites nova sp.
Nautilus cf. brahmanicus, Griesb.

(4) The beds with *Meekoceras*, *Proptychites*, etc., are overlaid by shales, 10 inches in thickness, followed by grey, shaly limestones, 7 inches, with a few fossils, which in their preservation are exactly like those of the upper division of the lower trias. No determinable ammonites have been obtained, one fragment, however, probably belonging to *Flemingites*, another apparently to *Clipites*. Higher up follow brown weathering limestones, with very thin shaly partings without fossils. The whole thickness of the beds between the topmost Otoceras beds (3 above) and the limestones with *Hedenstrœmia mojsisovicsi*, Dien., etc., (below), amounts to 4 feet 8 inches. Nothing definite can be said as to whether those few beds belong palæontologically to the overlying series, as might be supposed from their lithological aspect.

(5) The upper division of the lower trias is represented by a nodular limestone with very thin shaly partings, altogether 5 feet 7 inches thick. At Lilang ammonites are rather scarce and only the following few forms can be mentioned:—

Danubites nivalis, Dien.
„ *cf. ellipticus*, Dien.
Hedenstrœmia mojsisovicsi, Dien.

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[1] For reasons to be given below, the term "Subrobustus beds" is no longer appropriate.

Flemingites cf. sp. ind. ex. aff. trilobato, Dien.
Pseudosageceras[1] nov. sp.

(6) In the following group of beds, of 30 feet thickness, which consists of grey shaly limestones and grey shales, alternating very regularly, fossils are extremely rare, and very badly preserved. The series must, however, be included in the upper division of the lower trias.

(7) The next series consists of a nodular limestone of 60 feet thickness, again very poor in fossils. It most probably belongs, at least partly, to the lower muschelkalk. The nodular limestone is overlaid by black limestones, containing the lower muschelkalk cephalopod fauna, described by Prof. Diener from the Chitichun area.

Comparison with Painkhanda (Shalshal cliff section).

The Otoceras beds are in Spiti much thinner than in Painkhanda.[2] The thickness of unfossiliferous beds between both divisions of the lower trias is very inconsiderable in Spiti, as limestones, very rich in *Meekoceras* are present between the "main layer of *Otoceras woodwardi*" and the upper division of the lower trias. The lower trias is separated from the fossiliferous lower muschelkalk by a thick nodular limestone, probably of lower muschelkalk age, which is not recorded from other parts of the central Himalayas.

Correlation with Salt Range.

Prof. Diener correlated the "main layer of *Otoceras woodwardi*" with the unfossiliferous shales and sandstones at the base of the lower ceratite limestone of the Salt Range. At the same time he considers the unfossiliferous beds, present in the middle of the lower trias of Painkhanda, equivalent to the lower ceratite limestone and the ceratite marls.

The researches in Spiti have led to a different result. As stated above, there is only a very inconsiderable thickness of practically unfossiliferous beds between the two divisions of the lower trias. Therefore these cannot possibly be of very different age. Moreover, palæontological evidence tells against Prof. Diener's correlation. The question will only be discussed very shortly here, but I hope to be able before long to give a full palæontological account of the fauna of the lower trias of Spiti, and its relation to the lower trias of the Salt Range.

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[1] The genus *Pseudosageceras*, created by Prof. Diener, had so far only been known from Eastern Siberia (Mémoirs du Comité Géologique St. Petersburg, vol. XII, No. 3, 1895).

[2] See Griesbach, Mem. XXIII, pp. 144 to 147, Diener, Denkschriften d. k. Akademie der Wissenschaften, Vienna, 1895, p. 582, and Pal. Ind., l. c., p. 3.

For the present the following might be mentioned:—

Several ammonites recently collected from the otoceras beds of Spiti are either identical with, or very closely allied to forms from the ceratite marls of the Salt Range, *viz.*:—

Proptychites ammonoides, Waag.
" *sp. aff. latifim briattus*, Waag.
Meekoceras cf. pulchrum, Waag.

Here also *Meekoceras varaha*, Dien., has to be mentioned, which proved to be of closer affinity to "*kingites*" *lens*, Waag., of the ceratite marls, than was hitherto admitted by Prof. Dien.[1]

The following three species are identical with, or very intimately related to forms described from the lower region of the ceratite sandstone of the Salt Range, *viz.*:—

Danubites radians, Waag. sp.
" *rotula*, Waag. sp.
Meekoceras aff. radiosum, Waag.

The specimen mentioned above as *Danubites radians*, Waagen, was recorded in last year's General Report as a new species, because it differs slightly from *D. radians* by having a somewhat flattened external part. A closer examination has, however, convinced me that it cannot specifically be separated from the Salt Range species. A probably older variety of this species, with very sharp marginal edges occurs at Lilang in a bed, which I believe to be equivalent to the main layer of "*Otoceras woodwardi*" of the Shalshal cliff section.

The palæontological evidence recorded above leads to the conclusion that the Otoceras beds are equivalent to the ceratite marls, and the lower ceratite sandstones of the Salt Range.

So far there is no decisive proof that the lower ceratite limestone is also represented in the Otoceras beds, although this is very probable for stratigraphical reasons. This is also indicated by certain faunistic affinities already recognized by Professor Diener (Pal. Ind., l. c., p. 176).

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[1] Pal. Ind., Ser. XV, Vol. II, Pt. 1, p. 144.

The upper division of the lower trias has been correlated by Professor Diener with the whole ceratite sandstones of the Salt Range.[1] From what has been said above, it appears much more probable that the upper division of the lower trias of the Himalayas corresponds only to the two higher divisions of the ceratite sandstones, *viz.*, the Stachella beds and the *Flemingites flemingianus* beds. This also agrees better with Professor Diener's own results. Of the eight species from the upper part of the lower trias, which he mentions as being either intimately connected or probably identical with Salt Range species, he refers five to forms occurring in the middle and upper stage of the ceratite sandstones. He compares one with a species of the passage beds between the ceratite sandstones and the upper ceratite limestone, another to a species of the upper ceratite limestone. Only a single species is referred to a form known from the lower ceratite sandstones.[2]

The lower trias of the Salt Range and the Himalayas will therefore have to be correlated as follows:—

	Salt Range.	Himalayas.
Ceratite sandstones	Fl. flemingianus beds. Stachella beds. Lower stage of C. S.	Upper stage of ower trias.
	Ceratite marls Lower ceratite limestone	Otoceras beds.

Lower Muschelkalk.

Fauna of the "Middlemiss crag" of Hundes discovered in Spiti.

One of the most interesting results of the stratigraphical researches in Spiti consists undoubtedly in the discovery in several localities of the lower muschelkalk cephalopod fauna, which was described by Professor Diener chiefly from the eastern slope of the limestone crag Chitichun No. 1 north-west of Lochambelkichak encamping ground in Hundes.[3]

This fauna was discovered by Mr. Middlemiss in a few blocks of red limestone, imbedded in Spiti shales, under conditions which did not allow of its stratigraphical position being ascertained. The fossils were chiefly derived from red crinoid limestone layers, intercalated in red, and red and white coloured limestone. No stratigraphical evidence being available, the age of this fauna had to be decided by its fossils contents only. The result arrived at by Professor Diener was, that it must belong to the lower muschelkalk.

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[1] Pal. Ind., Ser. XV, Vol. II, Pt. 1, l. c. p. 177.

[2] Pal. Ind., Ser. XV, Vol. II, Pt. 1, l. c. pp. 175, 177 and Waagen, Fossils of the ceratite formation.

[3] Pal. Ind., Ser. XV, Vol. II, Pt. 2, pp. 101 to 108, Pl. XXIX to XXXI.

This fauna was found in Spiti at the base of the beds with *Spiriferina stracheyi*. Thus the view expressed by Professor Diener as to their age is proved to be correct. The limestone in which the fossils are imbedded is of a character different from that of the crags of Chitichun, being black, very hard and tough limestone.

We have seen above that the lower trias ends at Lilang with a nodular limestone of 60 feet thickness, which in all probability belongs partly to the lower muschelkalk. On top of this limestone follow:—

1. Six thin layers of hard, grey, partly concretionary limestone, together of 3 feet 2 inches thickness, which yielded no fossils.
2. This sequence is again overlaid by a band of hard, dark grey, very tough limestone, only 4 inch thick, which yielded a comparatively large number of ammonites. Commonest amongst them is a new species of—

Hungarites,

distinguished by very indistinct marginal edges. Another species, which is rather common, though obtainable in fragments only, is

Ceratites subrobustus, Mojs.

The specimens are perfectly identical with Professor Diener's type specimen as far as their sutures are concerned. They differ somewhat in sculpture, but the differences are not more considerable than between the specimen from Rimkin Paiar and the figures in Mojsisovics's "Arktische Trias Fauna."

The genus *Monophyllites* also plays an important rôle, and most of the species may be identified with species from Chitichun, or are closely related to forms described from Tibet. They are the following:—

Monophyllites confucii, Dien.
" *pitamaha* "
" *aff. Kingi.* "
" " *hara.* "
" *sp. group of M. Suessi*, Mojs.

Another characteristic and common species of these beds is

Sibirites prahlada, Dien.

described from the beds with *Spiriferina stracheyi*, Salter (see below). Besides this, there occur—

Gymnites ugra, Dien.
Danubites kansa, Dien.

both known from Chitichun, and a new species of

Prosphingites.

3. On top of this thin band with ammonites of lower muschelkalk age, lies a thin limestone bed (3 inch) with a fragment of *Spiriferina sp.* and

4. Immediately overlying the latter is a bed of 4 inches, with—

Spiriferina stracheyi, Salter.
Spirigera (*Athyris*) *stoliczkai*, Bitt.
Terebratula (*Dielasma*) *himalayana*, Bitt.
Rhynchonella mutabilis, Stol.

and other brachiopoda.

5. Two grey, concretionary limestone beds, 3 inches each, with brachiopoda, which have not yet been specifically determined in detail, and

6. Two beds of grey limestone, together of 16 inches, both containing

Xenaspis, nov. sp.

and a species of *Ceratites*, very similar to *Ceratites ravana*, Dien.

7. Immediately above this bed follows the well known Himalayan upper muschelkalk, with its rich fauna of *cephalopoda*. Shales are everywhere intercalated between the limestones, but decrease more and more in thickness towards the top.

This same limestone is *in situ* at also several other localities, *viz.*, 2 miles below Tangachenmo encamping ground, Gyundi river and in the Thanam valley; north-west of Lilang on the right bank of the Lingti river. At Muth a very good specimen of *Ceratites subrobustus* was found in a shaly layer in the immediate vicinity of (probably below) the beds with *Spiriferina stracheyi*.

From the Gyundi river there have to be mentioned—

Danubites kansa, Dien.
Gymnites ugra, Dien.

and several new species of *Gymnites* and *Ceratites*.

The ammonites collected north-west of Lilang are—

Ceratites subrobustus, Mojs.
Sibirites prahlada, Dien.
Monophyllites pitamaka, Dien.
„ *aff. hara.*, Dien.
„ „ *kingi.*, Dien.
„ *nov. sp. group of Monoph. Suessi*, Mojs.
„ *Hungarites nov.* sp.

The small collection from the Thanam valley has not been examined in detail, but the presence of *Monophyllites* was ascertained.

Term "Subrobustus beds" no longer appropriate.

Prof. Diener divided the lower trias into two stages. He named the upper one "Subrobustus beds," as he obtained from its topmost bed[1] *Ceratites subrobustus* along with *Flemingites rohilla*.[2] The term "subrobustus beds" is, however, no longer appropriate, because *Ceratites subrobustus* occurs also higher up in the lower muschelkalk. This term had therefore best be discarded altogether as otherwise it might lead to misinterpretation.

"Horizon of Sibirites prahlada," Dien., not identical with the beds with Spiriferina stracheyi, Salter.

Sibirites prahlada, Dien., was recorded by Professor Diener to occur in the limestones with *Spiriferina stracheyi*. Consequently these brachiopod-beds were termed the "horizon of *Sibirites prahlada*.[3] This is not in accordance with my own observations, as I found *Sibirites prahlada* in beds underlying, but never in the limestone with *Spiriferina stracheyi* (see above). Professor Diener recently informed me by letter, that he had not collected *Spiriferina stracheyi* along with *Sibirites prahlada*. In the Shalshall cliff section, where he found *Sibirites prahlada*, no brachiopoda were found with it, while the brachiopoda mentioned by him were derived from a second locality further down the valley.

Thus there is no proof that *Sibirites prahlada* and *Spiriferina stracheyi* occur together, and we have to distinguish between cephalopod beds with ammonites of lower muschelkalk age and the

[1] Pal. Ind., Ser. XV, vol. II, pt. 1, p. 22.

[2] Communicated by letter.

[3] Pal. Ind., Ser. XV, Vol. II, pt. I, pp. 3 and 5, Denkschriften d. k. Akad. d. Wissenschaften, Vienna, 1895, p. 571.

brachiopod beds with *Spiriferina stracheyi*, in which so far no ammonites have been discovered.

Above the muschelkalk follows a group of limestones, which can be subdivided into :—

		feet.
Upper Carnic stage.	4. Hard, black, splintery limestone, somewhat bituminous, with calcite veins, weathering greyish brown, intercalated with shaly limestones in layers of one to three feet.— *Halobia cf. comata*, Bitt. „ *cf. fascigera* „ Representing part of the "Horizon of *Halobia comata*," Bitt.	111
	3. Black limestones as 4, intercalated with shales. Very large *Arcestes* sp.	25
Lower Ladinic stage.	2. Hard, black limestone as 4. *Daonella cf. commeli*, Waag. . . .	145
	1. Series of thin-bedded, black, shaly limestones and earthy shales, with some hard, black, brown weathering limestone beds . .	160
	Towards the base rich in Cephalopoda (see below). *Daonella indica*, Bitt. „ *commeli*, Waag.	

Horizon of *Daonella indica*, Bitt.

The most important of these four stages is the lowest one. This will have to be dealt with in detail since our researches have led to an entirely different result as to the age of this stage.

Professor Diener observed a crinoid limestone (Traumatocrinus limestone) in the Shalshal cliff section above the upper muschelkalk, from which he collected a number of ammonites which Mojsisovics declares to belong to his " Aonoides zone." Thence these observers assume that the upper muschelkalk is directly overlaid by deposits of upper carnic age, and also they believe that the ladinic and lower carnic stages are absent. It is very important to emphasize that this assumption of a break in this section is by no means supported by the geological evidence. Professor Diener himself, when examining the Traumatocrinus limestone, took it to be a division of the muschelkalk "as it appeared to be perfectly conformable upon the Ptychites beds and to be stratigraphically intimately connected with them." [1]

No break in the succession of triassic beds in Spiti.

Representation of ladinic deposits fully ascertained.

In Spiti we have observed nothing which could be interpreted as a break in the sequence of triassic beds. Moreover the examination of the fossils collected from the muschelkalk and its overlying beds, has proved with certainty that such a break cannot possibly exist. The material collected in various localities has been worked out sufficiently in detail to decide this question.

There are altogether four points which prove that ladinic deposits do exist in Spiti.

a. Four species of ammonites and one of *Spirigera* are common to both the upper muschelkalk and the beds with *Daonella indica*, *viz.*,—

Proarcestes bicinctus, E. v. Mojs.
Ptychites gerardi, Blanf.
Hungarites nitiensis, E. v. Mojs.
" *nov. sp.*
Spirifera kunica, Bitt.

Proarcestes bicinctus has been described from the upper muschelkalk of Spiti. Last year it was collected by us at Raga in Spiti, from a limestone bed with *Monophyllites* sp. ind. group of *M. sphærophyllus*, *Ptychites gerardi* and *Ptychites asura*, Dien. The same species was also obtained at Ranna in the Thanam valley, and in another locality in the Thanam valley by Mr. Hayden, and south-east of Muth by us both. In all these last mentioned localities it was found to be abundant in the topmost bed of the upper muschelkalk, being associated with *Sturia Sansovinii*, Mojs., *Proarcestes balfouri*, Opp., *Ptychites gerardi*, Blanf., and other characteristic species of the upper muschelkalk.

But *Proarcestes bicinctus* is also quite as common in the beds with *Daonella indica*, Bitt. I have collected numerous specimens from the beds north of Po.

Ptychites Gerardi, Blanf., has long been known as a typical fossil of the Himalayan muschelkalk. However, this species is not confined to the muschelkalk, but, like *Proarcestes bicinctus*, reaches up into the beds with *Daonella indica.* E. v. Mojsisovics in his recent Memoir on the cephalopoda of the upper trias of the Himalayas (Pal. Indica, Ser. XV, Vol. III, Pt. 1, p. 117, Pl. XIX, figs. 8 and 9) described from the black limestone, facing the Ralphu glacier, regarded as equivalent to the *Traumatocrinus* limestone of Rimkin Paiar, a species which he names *Ptychites posthumus.* This species in my opinion is identical with the well-known muschelkalk species *Ptychites gerardi,* Blanf. This is clear from the shape of the shell and from the suture lines. The latter show the same semicircular arrangement as in *Ptychites Gerardi,* and also a bipartite second lateral, and first auxiliary saddle. It must be remarked that the figure of the sutural line of *Ptychites posthumus* in E. v. Mojsisovics's Memoir is not quite correct, as the median incision of the second lateral saddle is not represented deep enough, while the branches of the first auxiliary saddle are drawn too slender. In reality these two saddles are of almost equal size in the type-specimen, which I have re-examined. I collected two small specimens of *Ptychites* identical with *Ptychites posthumus* = *Ptychites Gerardi,* Blanf., from the beds with *Daonella indica* north of Po.

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[1] Denkschriften der k. Akademie der Wissenschaften, Vienna, 1895, p. 547. Pal. Ind., Ser. XV, Vol. III, Pt. 1, pp. 127, 128, and 135.

Hungarites nitiensis, Mojs., had so far only been known from the crinoid limestone of Rimkin Paiar, and from beds of unknown age of the Niti pass. This species was found by Mr. Hayden in the Thanam valley, in beds immediately overlying the muschelkalk. But we also collected it from the muschelkalk of Kaga. The identity of the species could be fully established, thanks to the fortunate fact that I was able to compare it with the type-specimen from Rimkin Paiar. The *Hungarites* nov. spec. mentioned above, is a very characteristic species, having transverse folds of a most distinct falciform bend as in *Harpoceras,* but it bears no resemblance to any of the Alpine species. It occurs in the muschelkalk of Kaga, in the topmost bed of the muschelkalk at Banna encamping ground, Thanam valley, and in the ladinic beds immediately overlying the topmost muschelkalk in another locality in the Thanam valley (collected by Mr. Hayden).

Spirigera hunica, Bitt., was described from the beds with *Daonella indica* from the Shal-Shal section and other localities. It has also been found in Spiti (north of Po, west of Lilang) in these beds, but the same species occurs in the topmost beds of the muschelkalk at Banna encamping ground and south-east of Muth.

Besides these five species, ranging from the muschelkalk into the beds with *Daonella indica*, *Arpadites stracheyi*, Mojs., has to be dealt with.

This form is described and figured on page 58, of E. v. Mojsisovics's recent publication, from a plaster cast of the original specimen collected by General Sir Richard Strachey on the Niti pass. It had formerly been figured by Salter and Blanford in the Palæontology of Niti, pl. 8, fig. 3. E. v. Mojsisovics attributed this species to the ladinic stage, assuming that it was derived from beds homotarial to the Traumatocrinus limestone of Rimkin Paiar. On the topmost bed of the muschelkalk at Banna encamping ground Mr. Hayden collected several specimens of an *Arpadites*, which in my opinion are identical with *Arpadites stracheyi*, Mojs. They most strikingly recall the species from the Niti pass in general shape, especially by their obliquely elliptical outline. The external part agrees perfectly with the description given by Dr. v. Mojsisovics, as the marginal edges are not yet visible at the beginning of the last volution, and become more and more distinct towards the anterior termination. Small, slightly curved, transverse folds are visible on the anterior half of the last whorl. The sutures on the whole correspond to the illustration in the Palæontology of Niti, pl. 8, fig. 3 d. There is a very low siphonal tubercle (though slightly higher than in the figure), each branch of the siphonal lobe terminating in one point. The lateral lobes do not correspond to the figure in the minor details, their dentation being deeper and not quite as numerous. The saddles are more slender than in Salter's figure. But the number of lobes and saddles agrees with the figure, and as for the differences mentioned, they might well be due to incorrect drawing. The sides of the chambered part of the Spiti specimens are covered with short, rather strong, radial folds, which only become weaker and falciform towards the anterior termination. Such folds are not visible in the figure of the plaster cast in Mojsisovics's Memoir, but they are indicated in Salter's figure pl. 8, fig. 3a. Owing to the insufficient knowledge of the specific characters of *Arpadites stracheyi*, the identity of the Spiti specimens with those from the Niti pass cannot be fully ascertained, but it is at least highly probable that this species also occurs in the uppermost beds of the muschelkalk.

b. Besides the forms, which are identical with upper muschelkalk species, one new species, which is closely allied to a muschelkalk species, must be mentioned from the beds with *Daonella indica, viz.:*

Ceratites nov. sp. aff. Cer. Himalayanus, Blanf.—It is only distinguished by more complicated sutures and a wider umbilicus, as the involution takes place outside the spiral row of lateral tubercles (north of Po and Thanam valley).

c. Four species recently collected from the beds with *Daonella indica* are either identical with, or closely allied to European forms from deposits of ladinic age, namely:—

Gymnites ecki, E. v. Mojs.
Hungarites aff. mojsisovicsi, Boeckh.
Trachyceras archelaus, Laube.
Trachyceras aff. ladinum, E. v. Mojs.

Daonella Lommeli, Wiss., collected years ago by Mr. Griesbach south-east of Muth, must be added to these forms. The occurrence of this species has already been pointed out by Dr. A. Bittner as an indication that ladinic deposits might be present in the trias of Spiti.[1] As to *Gymnites ecki*, E. v. Mojs., although the sutures could not be compared in detail with those of European specimens, the specific identity may be said to be indisputable; north of Po.

Hungarites aff. mojsisovicsi, Boeckh, is very similar to the European form, but here again the sutures cannot be compared in detail. The only specimen obtained north of Po is smaller than the two specimens figured in E. v. Mojsisovics's "Cephalopoden der Mediterranen Triasprovinz."[1] It has a diameter of 46 mm. and is distinguished from the Hungarian forms by a less prominent median keel and a slightly more pronounced falciform bend of the transverse folds.

The forms mentioned as *Trachyceras ladinum*, E. v. Mojs., cannot be distinguished from the Alpine species, corresponding as they do completely in the arrangement and number of the spiral rows of tubercles. The marginal thorns are perhaps somewhat more pronounced, but the difference is too slight to be of any importance. Found north of Po.

Trachyceras aff. archelaus, Laube, is very closely allied to the European species, to which it corresponds in its general shape and in the number of spiral rows of tubercles. Thanam valley,

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[1] Jahrbuch der Geol. Reichsanst., Vienna, 1899, p. 695.

Colln. Hayden; North of Po.

Daonella lommeli, Wiss., had, as above mentioned, already been known from Spiti. We found *Daonella lommeli* even more common than *Daonella indica* and obtained a considerable number of specimens from various localities.

d. Besides the palæontological evidence recorded above, the following fact tells against the assumption of a break in the succession of beds. In several sections in Spiti we collected the true *Joannites cymbiformis*, Wulf., along with a species closely related to *Trachyceras aonoides* in beds, situated from 400 to 450 feet above the upper muschelkalk (see below).

This will suffice to show that, so far as Spiti is concerned, there is no doubt that the ladinic stage is well developed. Dr. Bittner was therefore perfectly right in this point, although his surmise that the ladinic stage might be represented in Spiti was founded only on the occurrence of *Daonella lommeli.* In Spiti the passage from the muschelkalk into the ladinic is palæontologically such a gradual one, that, were it not for a lithological change, it would be difficult to define the horizons.

We have now to consider whether the arguments brought forward in favour of a break in the Shal-Shal cliff section hold good.

Age of the Traumatocrinus limestone of Rimkin Paiar.

The Traumatocrinus limestone of Rimkin Paiar has been looked upon as upper ladinic, principally because the following two species of ammonites occur in it:

Trachyceras tibeticum, E. v. Mojs.
"*Joannites aff. cymbiformis*, Wulf."

The accuracy of the determination of the latter species is extremely doubtful. Of the two specimens, which chiefly served for description, the smaller one (pl. XX, fig. 3, E. v. Mojsisovics, Pal. Ind., Ser. XV, vol. III, pt. 1) has only six saddles outside the umbilical margin, while *Joannites cymbiformis* has eight. The second and the larger specimen, the sutures of which have been figured on pl. XX, fig. 4, l. c., is distinguished from *Joannites cymbiformis*, Wulf., by the entire absence of varices. This fact was noticed, but apparently deemed unimportant by E. v. Mojsisovics (page 101 l. c.). Species similar to *Joannites cymbiformis* occur already in the muschelkalk. At Kaga two small specimens were collected by Mr. Hayden in 1898, and mentioned in last year's Annual Report, page 16, as *Joannites aff. diffissus*, Hauer. But Prof. Diener, to whom they had been sent for examination, determined them as probably *Joannites cymbiformis*, Wulf. It is therefore quite natural that similar forms should also be present in the ladinic beds. However, it must be borne in mind that none of the muschelkalk and ladinic types are actually identical with the true *Joannites cymbiformis*, which species, as already mentioned, occurs from 400 to 450 feet above the muschelkalk.

Trachyceras tibeticum, E. v. Mojs., which has not been found yet in Spiti, is no doubt closely allied to the carnic *Trachyceras austriacum*, as has been stated by E. v. Mojsisovics. It differs in having simpler sutures and in the characters of the external part. Dr. v. Mojsisovics himself considers *Trach. tibeticum* a new species, or if not, a variety of the Alpine *Trach. austriacum*. This being the case, I do not see why its occurrence in the Traumatocrinus limestone should not be explained more naturally by assuming that an older variety of the carnic *Trachyceras austriacum* of Europe appears in the Himalayas already in ladinic deposits.

Certainly, the evidence brought forward in favour of the correlation of the Traumatocrinus limestone with the upper carnic of the Alps is not a convincing one, and there is so far, not sufficient reason for supposing that in Painkhanda the ladinic stage, so well developed in Spiti, should be wanting.

As to the remainder of the argument, subdivided above into four different parts, the following may be noted.

Thickness of ladinic stage.

The hard, black, splintery limestones No. 2 yielded among other fossils a fragment of *Daonella cf. lommeli*, Wiss., derived from the base of the upper third of this limestone mass. I therefore include the black limestone No. 2 with the ladinic. This stage thus has a thickness of approximately 300 feet.

At Kuling we discovered a great many specimens of *Daonella lommeli* in shaly beds alternating with dark, splintery limestones. Among these there are unusually large specimens, measuring about 100 mm. from the umbo to the opposite margin of the shell. As the beds, from which we collected, were vertical, their stratigraphical position could not be ascertained. My opinion is that they belong either to No. 1 or No. 2 of the above sub-division. There is certainly no reason to suppose these beds equivalent to No. 3 or No. 4, as in spite of careful search in undisturbed beds opposite Lilang I have never met with a *Daonella lommeli* higher up than in the upper third of series No. 2.

Horizon of Halobia comata, Bitt.

On the other hand series 4 yielded two specimens of *Halobia*, which should in all probability be referred to *Halobia fascigera*, Bitt., and *Halobia comata*, Bitt.

No. 4 therefore corresponds to part of the "horizon of *Halobia comata*," Bittner, which according to this author represents or at least includes the equivalents of the Alpine Lunz-Raibler beds.[1]

Above the series of black limestones, recorded above, thick grey, earthy shales, in which grey, shaly limestones of various thicknesses are intercalated throughout Spiti. The series is of so uniform a character, that it can hardly be subdivided, unless in a very detailed fashion. However the following three divisions may be distinguished—

3. Grey, shaly limestones, alternating with calcareous, earthy shales.
2. Thin-bedded, shaly grey limestones about 20 feet.
1. Grey earthy shales, with numerous thin shaly limestone beds.

The thickness of this series amounts to at least 500 feet, the thin-bedded limestone 2 keeping about the middle of the system.

As to fossil contents two fossiliferous horizons may be mentioned. The lower one situated at the very base of the series, lying immediately on the topmost hard splintery limestones referred to above. The upper fossiliferous horizon occurs in part 3 of this series and consists of limestones, rich in *brachipoda*, situated about 40 feet above the thin-bedded limestone No. 2. The lower fossil horizon is of considerable importance. Mr. Hayden first recognised that the grey, shaly beds at the base of this series contained specimens of *Trachyceras*, closely allied to *Trachyceras aonoides*, E. v. Mojs. His collections from these beds 4 miles west of Thabo in 1898 comprise the following species.[1]

Shales with Joannites cymbiformis, Wulf.

Joannites cymbiformis, Wulf. (3)
Hauerites nov. sp. (1)

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[1] Pal Ind, Ser. XV, Vol. III, Part 2, p. 47 (in the press).

Trachyceras cf. aonoides, E. v. Mojs. (1)
" *nov. sp. aff. ariae*, E. v. Mojs. (1)
" *sp. ind.* (several fragments).

The only fossil of these collections, which could be identified with certainty, is *Joannites cymbiformis*, Wulf. As to *Trachyceras cf. aonoides*, it cannot be said to be perfectly identical with the European types, but so much is certain, that it resembles none of the European forms of *Trachyceras* as closely as it does *Trachyceras aonoides*.

As to last year's collections from the shales with *Joannites cymbiformis*, the following discoveries were made :—

1. Several fragments of a small *Trachyceras* which in sculpture and transverse section strongly recall such forms as *Trachyceras ariae*, E. v. Mojs. (" Gebirge um Hallstadt," pl. Clxxvi, fig. 3) or *Trachyceras griseldis* (l. c. pl. Clxxviii, fig. 1), collected at Banna encamping ground, Thanam valley, by Mr. Hayden.
2. Crushed specimens of *Trachyceras*, closely resembling in sculpture *Trachyceras aonoides* (north-north-west of Muth, Spiti, coll. Krafft, right bank of Lipak river, above Lipak encamping ground, coll. Hayden).
3. *Joannites cymbiformis*, Wulf (1 spec.) same locality. The specimen is entirely chambered and measures 80 mm. in diameter, the last volution being 43 mm. high. There are three varices on the last volution. Number of saddles outside the umbilical margin eight, corresponding to those of *Joannites cymbiformis*. This species was collected by Mr. Hayden above Lipak E. G.; fragments of *Joannites cf. cymbiformis* were obtained by him at Banna encamping ground; west of Lilang, and between Pomcrang and Mani.
4. *Drepanites* nov. sp. ind. 4 miles west of Thabo; coll. Krafft.
5. *Hauerites* nov. sp. (fragment) Banna encamping ground; colln. Hayden, resembling the Noric *Hauerites raristriatus*, E. v. Mojs., but differing in its sutural lines. This species was collected by Mr. Hayden 4 miles west of Thabo.

The second fossiliferous horizon of the system of grey beds was discovered north-north-west of Lilang. With the exception of one ammonite and some bivalves it yielded chiefly *Brachiopoda*. Of these only

Brachiopod beds.

Spiriferina shalshalensis, Bitt.
Rhynchonella lankana, Bitt., *and Discina* sp.

could be identified with species described from the trias of the Himalayas.[1] The bulk of the collections made, which comprise numerous well preserved specimens, belongs to species not recorded yet from the Himalayas. They have not yet been worked out in detail.

The only ammonite collected from this horizon is a small specimen very similar in its general shape, sculpture and the character of the external part, to the noric *Distichites goebli*, E. v. Mojs. (Gebirge um Hallstadt, pl. CXLIX), but distinguised by ceratitic sutures. The number of saddles and lobes is the same.

Above the series of shaly beds just referred to is a sequence of beds which still keeps up to a considerable extent the lithological character of the underlying beds, but is richer in intercalated limestone layers. This series may be said to consist chiefly of three kinds of strata, *viz*. (1) black, splintery, thin-bedded limestones, mostly concretionary and with brown dolomitic patches, (2) light grey, shaly limestones, (3) grey crumbling shales. These three kinds of deposits alternate very regularly and acquire a thickness of from 600 to 700 feet This series is not very rich in fossils, and those that are present are either badly crushed or otherwise insufficiently preserved. About the middle of the series occur large bivalves and very small *Brachiopoda*, which have not yet been worked out. Higher up, about 400 to 500 feet above the base of the series, a brown weathering, nodular limestone alternating with grey, crumbling shales, was observed, which has yielded cephalopoda of the genus *Tropites* and other genera. Unfortunately well preserved specimens are extremely rare. The collections recorded below were derived from the sections round Lilang and comprise the following species.

Nodular limestone with Tropites, etc.

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[1] Bittner, Pal. Indica l. c.

Tropites cf. subbullatus, v. Hauer
(badly preserved specimens)

Tropites cf. discobullatus, E. v. Mojs.

The specimens are extremely like those on pl. CIV in E. v. Mojsisovics's Gebirge um Hallstadt. The sculpture on the external part of the last volution is identical with fig. 1 c, pl. CIV. The sutures differ slightly. Whether this form is identical with the *Tropites ind. cf. discobullatus*, described by Mojsisovics from Kalapani[1] is uncertain, the latter being too badly preserved for close comparison.

Tropites (*Paratropites*) *nov. sp.*
" *cf. fusobullatus*, E. v. Mojs.
" *cf. torquillus*, E. v. Mojs.
very closely allied to the European species.
Many indeterminable fragments of *Tropites*.
Juvavites aff. bacchus, E. v. Mojs.
" *sp. ind. cf. J. bacchus*, E. v. Mojs.
Sagenites sp. aff. crinaceus, E. v. Mojs.
" *n. sp. aff. herbichi*, E. v. Mojs.
Sandlingites n. sp. ind.
Sirenites n. sp. ind.
? *Heraclites* sp. ind.; two different species, resembling *Heraclites*, especially *Heraclites bellonii*, E. v. Mojs., in general shape and sculpture, but differing from *Heraclites* by ceratitic sutures.
Clydonautilus griesbachi, E. v. Mojs.
Nautilus sp., three different species.

There can be very little doubt that this limestone with *Tropites* corresponds to the Tropites limestone of Kalapani, which E. v. Mojsisovics considers to be homo-taxial to the subbullatus beds of Hallstadt. As the stratigraphical position of the Tropites limestone of Kalapani is not known exactly, it is of considerable importance that the position of the Tropites beds has been fully established nevertheless.

About 70 feet above the nodular limestone with *Tropites*, a few large specimens of *Parajuvavites* nov. sp. were collected from grey shaly limestones. These beds will have to be included in the

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[1] Pal. Ind. l. c., p. 48, pl. XI, fig 7.

Tropites beds, as the same new species of *Parajuvavites* probably occurs in the latter[1] also.

"Zone of Clydonautilus griesbachi untenable."

Clydonautilus griesbachi—is, according to E. v. Mojsisovics the leading fossil of the "Hauerites beds". In Spiti these have been traced about 500 feet above the Tropites limestone (see below). I have never met with *Clydonautilus griesbachi* in any other horizon but the Tropites limestone, where I collected a good specimen west of Lilang. It appears that this species ranges through a considerable thickness of beds. The zone of *Clydonautilus griesbachi* introduced by E. v. Mojsisovics to replace Diener's term *Hauerites beds*[2] is very probably untenable.

The uppermost beds of the series referred to above, gradually pass into a mass, chiefly of dolomitic limestone. At its base this consists of black, concretionary, hard limestone beds such as are found in the underlying beds. But it becomes greyer in colour and more and more dolomitic higher up, where it is very thickly bedded. The whole thickness of this limestone mass amounts to about 300 feet.

A few bivalves and brachiopods were collected from this limestone. These were sent for determination to Dr. Bittner, as they appeared to be allied to characteristic alpine forms. As no answer has so far arrived from him, I am unfortunately unable to give any particulars about these fossils.

According to Prof. Diener the Daonella beds, *viz.*, the whole thickness of deposits included between the upper muschelkalk and the Hauerites beds amounts in Painkhanada and Johar to 600 to 750 ft.[3] The beds which in Spiti correspond to Prof. Diener's Daonella beds are much thicker, amounting to nearly 2,000 feet, or roughly three times the thickness of the latter.

The thick, dolomitic limestone mass just referred to, is overlaid by a system, chiefly composed of brown weathering sandy and shaly limestones. In this series, which amounts to about 500 feet, grey crumbling shales, alternating with brown limestones also occur in the upper half. Black, splintery limestones are met with near the base. About the middle of the series occur brown flaggy sandstones, showing beautiful false-bedding and with indistinct *plant* remains.

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[1] Found loose in the Tropites beds, under conditions which make it very improbable that it should have rolled down from higher beds.

[2] Pal. Ind., Ser. XV, Vol. III, pt. I, p. 136.

[3] Denkschriften l. c., p. 582.

Beds with (?) Hauerites n.p. ind., E. v. Mojs.

Amongst the fossil contents the following may be mentioned. I collected a specimen of *Hauerites* near the base of the series, at Chabrang, in brown weathering sandy limestones. This appears to be identical with the ? *Hauerites n. f. ind.* the sutures of which have been figured in E. v. Mojsisovics's recent Memoir. Along with this species occurs a very large *Paratibetites*, closely allied to *Paratibetites tornquisti*, E. v. Mojs. It differs only slightly in the suture lines. Besides this, several specimens of *Hauerites*, differing in sutures from that mentioned above, *brachiopoda* and bivalves, *viz.*, *Mysidioptera* sp., *Avicula* sp., *Modiola* sp., *Anodontophora griesbachi*, Bitt., a species of considerable vertical distribution. (See below and Bittner Pal. Ind. l.c., p. 61.)

Beds with Juvavites, etc., equivalent to the Halorites beds, Dien.; faunistic difference.

Above the fossiliferous strata just described, beds with numerous cephalapoda occur in the upper half of the system in all the sections examined. These from their stratigraphical position, and also to a certain extent owing to their palæontological character, must be looked upon as the equivalents of the Halorites beds, Dien.

By far the most prominent genus of these beds is *Juvavites*. Specimens of this genus are fairly common throughout Spiti although nowhere abundant. Among the forms collected there are a few specimens belonging to the group of the 'continui' E. v. Mojsisovics and allied to *Juvavites ehrlichi*, E. v. Mojs.[1] Other specimens, also few in number, belong to the group of the "intermittentes" and "scissi," E. v. Mojsisovics. But by far the greatest number is characterized by ribs crossing the external part with little, if any interruption; they are at the same time very strongly bent forward, a feature which distinguishes these specimens from all the species known from the Hallstadt limestone. Apart from this they exhibit the characters of the "continui."

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[1] The species is not identical with Griesbach's *Tropites Ehrlichi var. feistmanteli* nov. sp. Mem. XXIII, p. 142, described by E. v. Mojsisovics, l. c., p. 24, pl. VI., figs. 1, 2, 3 as *Parajuvavites feistmanteli.*

Besides forms belonging to the genus *Juvavites*, the following species have to be mentioned:

Paratibetites tornquisti, E. v. Mojs.
Tibetites cf. ryalli, E. v. Mojs.
Anatibetites nov. ?sp. aff. kelvini.

a very interesting species being distinguished from *Anatibetites kelvini* by incised saddles, while otherwise identical with it.

Clionites aff. hughesi, E. v. Mojs.
Dittmarites nov. sp.

differing from *Dittmarites hindei*, E. v. Mojs, by broader whorls and wider umabilicus,

Pinacoceras sp.
Phylloceras sp. ind.
Pleuronautilus sp. aff tibeticus, E. v. Mojs.

It is a very strange fact that not one of these species can be said to be perfectly indentical with forms described from the Bambanag section. The only species very closely allied to a described form is *Paratibetites tornquisti*, E. v. Mojs.

No Halorites discovered in Spiti.

It is also strange that not a single specimen of *Halorites* so common in the "Halorites beds" of the Bambanag cliff has been met with in Spiti. Neither is the genus *Parajuvavites* present in our collections, from the beds I am referring to, although a few specimens have been found lower down in beds which I included in the tropites beds (see above).

But for all that there can be little doubt that the beds with *Juvavites* must belong to pretty much the same horizon as the "Halorites beds," Diener. For they are overlaid by a coral limestone, with *Spiriferina griesbachi*, Bitt., which may safely be correlated with the "limestone with *Spiriferina griesbachi*" of the eastern Himalayas.

It appears from the above, that there is a remarkable faunistic difference between the "Halorites beds" of the more eastern Himalayas, and their equivalents in Spiti, for which so far no explanation can be given. The facies of these beds in Spiti is rather unfavourable for the preservation of fossils. This no doubt accounts for the comparative scarcity of the fauna.

Local limestone with Spiriferina griesbachi.

As mentioned before, the beds with *Juvavites*, etc., are overlaid by a grey limestone mass of about 100 feet in thickness. This is a true organigenic limestone, being composed almost entirely of fossil remains, among which *corals* and *Bryozoa* (?) are predominant. Besides this there are a few brachiopoda belonging to the species—

Spiriferina griesbachi, Bitt., and
(?) *Rhynchonella bambanagensis*, Bitt.

This limestone is no doubt equivalent to the "limestone with *Spiriferina griesbachi*," Dien.

Beds with Monotis salinaria, Spiriferina griesbachi, etc., equivalent to the "Sagenites beds," Dien.

The beds overlying the coral limestone are lithologically very similar to the beds below it. It is chiefly composed of brown-weathering, sandy, and shaly limestones, often dolomitic, with brown weathering sandstones, calcareous shales, and dark grey, hard limestones with brown dolomitic patches. The thickness of this series is about 300 feet. Palæontologically it is characterized by its richness in bivalves and brachiopoda, ammonites being extremely rare. The former must first of all be mentioned.

Monotis salinaria, Br.

The discovery of this characteristic bivalve, which now for the first time is recorded from the Himalayas, is due to Mr. Hayden. He found it to be abundant between Mani and the Pin river on the right bank of the Spiti river. Later on I traced it also in a section east, above Lilang, but it is by no means so common there as near Mani. The layer of *Monotis salinaria* is a light grey, somewhat shaly-limestone, situated east of Lilang about 200 feet above the coral limestone. It is particularly interesting to note that the mode of occurrence of *Monotis salinaria* is exactly the same in Spiti as in the Pamir, where Ferdinand Stoliczka collected the species north-east of Ak Tash, 4 miles west of the Neza-Tash pass.[1] Indeed hand-specimens from Spiti can scarcely be distinguished from those of Stoliczka's collections. Other fossils of this series are—

Anodontophora griesbachi, Bitt.
Spiriferina griesbachi, Bitt.

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[1] *E. Suess. Zur* **Stratigraphie Central-Asiens; Denkschriften der k. Akademie d. Wissenschaften, Vienna, 1894, p. 460.**

Rhynchonella bambanagensis, Bitt.
Aulacothyris joharensis, Bitt.
Spirigera dieneri, Bitt.
Distichites nov. sp. (fragments.)

Within this series, *Spiriferina griesbachi* was found in beds about 30 to 50 feet higher than the layer with *Monotis salinaria*. In the former horizon the rest of the species above mentioned, except *Spirigera Dieneri*, also occur; only one specimen of this species was found north of the Manirang pass in a shaly bed, immediately above the coral limestone.

The specimens of *Spiriferina griesbachi* of this stage are distinguished from those of the coral limestone below, by their remarkable size. Bittner[1] has already drawn attention to the close resemblance of *Spiriferina griesbachi* to Stoliczka's *Spiriferina tibetica* and *altivaga*, described as carboniferous forms. He considers it probable that these three species are identical. This is no doubt the case. Stoliczka's specimens cannot have been collected from the carboniferous, as nowhere in the true carboniferous of Spiti was found a brachiopod similar to *Spiriferina griesbachi*. Moreover, nowhere within many miles of Kibber, where Stoliczka found loose specimens of *Spiriferina tibetica*, do carboniferous rocks occur. On the other hand north of Kibber, near the Parang Lá, Mr. Hayden observed the beds with *Spiriferina griesbachi*, so that doubtlessly Stoliczka's loose specimens had come from these beds.

The localities from which *Spiriferina griesbachi* have been obtained are very numerous, indeed in every section of upper Trias examined, the species was found to be abundant.

As to ammonites, only fragments, apparently belonging to the genus *Distichites*, have to be recorded. The genus *Sagenites* has not been traced in these beds. However, there can be no doubt that the series with *Monotis salinaria*, *Spiriferina griesbachi*, etc., corresponds to those beds of Painkhanda and Johar which have been termed "Sagenites beds" by Prof. Diener.

Series of quartzites, limestones and shales with Spiriferina griesbachi, Bitt., and Aulacothyris joharensis, Bitt.

The beds with *Monotis salinaria* and *Spiriferina griesbachi*, etc., are overlaid by a series, characterized by the occurrence of white and brown quartzites. It forms a most conspicuous horizon throughout Spiti, and is often perceptible at great distances as a white band. Generally three different layers of quartzite can be distinguished, separated from each other in the lower part by limestones, but towards the top black, shaly beds are intercalated. The system varies rather in character. It will suffice to mention the sequence as observed near Lilang which is as follows :—

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[1] Jahrbuch d. geol. Reichsanstalt, Vienna, 1899, p. 696.

6. Great thickness of black and grey, dolomitic limestone.
4. Thick, brown quartzite.
5. Black sandy shales, with *Aulacothyris joharensis*, Bitt., alternating with thin brown quartzite layers; over 100 feet.
3. Thin band of beautifully white quartzite.
2. Dark grey, hard limestone, sandy or dolomitic, with brown dolomitic patches, and strange markings, probably representing sections of ? *Megalodon* or ? *Dicerocardium*, with *Spiriferina griesbachi*, Bitt. *Lima serraticosta*, Bitt.; about 200 feet.
1. Brown quartzite, about 20 feet.

Spiriferina griesbachi and *Aulacothyris joharensis* reach up from the lower beds into this horizon.

Thick sequence of limestones, representing Dachsteinkalk, in part Rhaetic, Lias and Oolite.

The beds above the quartzite series are of a very uniform lithological character. They consist of dolomitic, black or grey, somewhat earthy limestones mostly in thin beds. These, although acquiring a thickness of roughly 2,300 feet, do not change to any remarkable extent lithologically. With reference to this, I must, however, mention that about 400 feet above the quartzite series a white, dolomitic band of about 30 feet in thickness was observed in several sections. Frequently in these limestones red, dolomitic bands occur. Near Gieumal I observed about 80 feet below the Spiti shales, a brown quartzite of about 10 feet thickness. This may correspond to the conglomerate mentioned by Mr. Griesbach[1] as forming a contact bed between his upper lias and the Spiti shales, north of the Niti pass. However, it must be emphatically remarked that no trace of an unconformability can be observed. There is every evidence that the passage from this limestone sequence into the Spiti shales is a perfectly gradual one.

[1] Mem. XXIII, p. 126.

The limestone series below the Spiti shales is throughout—except in the uppermost layers—extremely poor in fossils, and those present are generally badly preserved. For this reason, only a few data can be given.

Since this limestone mass is capped by the upper jurassic [1] Spiti shales, and since not the slightest trace of a break in the sedimentation can be discerned, the limestone mass must needs represent the uppermost dachsteinkalk, rhaetic, lias and oolite. This is, however, only proved by fossils as far as oolite and trias are concerned. Certain discoveries point to lias, but no rhaetic fossils have, so far, been recognized.

The following fossils can be recorded:—

Dachsteinkalk in part.

1. ***Megalodon ladakhensis***, Bitt.[2], occurring at 50 feet above the quartzite series in a thick band almost entirely composed of *Megalodon*, at Hansi. This species was also collected by Mr. Hayden. Palang Buldur, Para river, Rupshu.
2. (?) *Spirigera Noetlingi*, Bitt., described in Bittner's recent Memoir "from beds of unknown age (presumably lias) from Nio-Sumdo in Karnag."

Lima cumaunica, Bitt.
,, *serraticosta*, Bitt.
Spiriferina nov. sp.

very similar to *Spiriferina griesbachi*, but without a median rib in the sinus of the large valve, and without a furrow in the lobe of the small valve.

All these forms were collected between 200 and 300 feet above the quartzite series at various localities.

3. *Gastropods* in bad preservation, among them a form, similar to *Naticopsis gradata*, Koken. About 400 feet above the quartzite series; east of Lilang.
4. Bivalves, chiefly *Pecten* and other genera, mostly preserved in casts, *corals*, etc., not yet worked out. Collected up to about 400 feet above the quartzite series.
5. 800 to 900 feet above the quartzite series I collected between Gieumal and Chabrang a few very well preserved specimens of *Spiriferina*, which bear a

Lias?

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[1] Denkschriften d. k. Ak. d. Wissenschaften in Wien, 1895, p. 587.
[2] Palæontologia Indica l. c.

striking resemblance to *Spiriferina obtusa*, Opp., of the Hierlatz limestone of the eastern Alps (Geyer, Liasische Brachiopoden des Hierlatz, Abhandlungen d. geol. Reichsanstalt, Vienna, 1889, pl. VIII). Although I should not like to attach any vital importance to this discovery, it is of interest, connected with the following observation.

Kelloway.

6. About 1,000 feet above the layer in which *Spiriferina cf. obtusa*, Opp., was obtained, and 370 feet below the base of the Spiti shales, a very well preserved ammonite was collected in the section between Chabrang and Gieumal. This is closely allied to *Stephanoceras coronatum*, Brug. (Explanations de la Carte Géologique de France, Tome IV, 1878, pl. LIV, fig. 2). In its transverse section, and the number of lateral tubercles (15 in the Spiti form, 14 in the European specimen referred to), there exists almost complete identity. There is only this noteworthy difference, that in the considerably larger specimen from Chabrang, the ribs are only very indistinctly developed on the siphonal part. Therefore they can only be seen in a side light. However, so much can be distinctly observed that two very flat folds rise from one tubercle crossing the external part in a forward-bent curve.

I do not hesitate in determining this ammonite as *Stephanoceras cf. coronatum*, Brug., and the beds including it must therefore be considered as Kelloway. The overlying beds of 370 feet in thickness, in places very rich in brachiopoda, will have to be included in the uppermost oolite.

Seeing that Kelloway is *in situ* 370 feet below the base of the Spiti shales, the lias must lie considerably lower. Therefore it is quite possible that the beds with *Spiriferina cf. obtusa* actually represent the lias. At any rate a great part of the limestone series in question must be of liassic and jurassic age. On the other hand there is little doubt that the lowest 300 to 400 feet are of upper triassic age, while higher up the rhaetic must be represented. To define the various horizons accurately will be a very difficult task, owing to the scarcity of determinable fossil remains.

Gieumal sandstones and Chikim limestone.

As to the beds following above the Spiti shales, I have only a few points to mention. Wherever well exposed, the Gieumal sandstone alternates at its base with the Spiti shales, a feature already observed by Messrs. Stoliczka, Griesbach and Diener. South of Gieumal many bivalves mostly of poor preservation occur. Near Chikim and Kibber we observed casts of ammonites belonging to *Perisphinctes* and *Stephanoceras*.

The Chikim limestone of Chikim itself has yielded *Foraminifera*, recorded already by Ferdinand Stoliczka. They belong to the genera

Cristellaria,
Dentalina, and
Haplophragmium.

In the Lingti valley a belemnite was observed in this limestone.

The sequence of beds included between the productus shales and the Spiti shales is given in the following table:—

SPITI SHALES. UPPER JURASSIC.

Grey and black earthy limestones, passing gradually into the Spiti shales. About 2,300 feet.	*Stephanoceras cf. coronatum*, Brug. About 1,800 to 1,900 feet above base.		Oolite
	Spiriferina cf. obtusa, Opp. About 800 to 900 feet above base.		... Lias. ... Rhaetic.
	? *Spirigera noetlingi*, Bitt. About 300 feet above base.	Dachsteinkalk in part.	Upper trias.
	Megalodon ladakhensis, Bitt. About 50 feet above base.		
White and brown quartzites, black shales and hard grey limestones. From 300 to 350 feet.	*Aulacothyris joharensis*, Bitt. Near top. *Lima cumaunica*, Bitt. *Spiriferina griesbachi*, Bitt. Lower Part.		
Brown weathering, sandy and shaly limestones, sandstones and dolomites. 300 feet.	*Spiriferina griesbachi*, Bitt. *Anodontophora griesbachi*, Bitt. *Aulacothyris joharensis*, Bitt.	Sagenites beds, Diener.	

Brown weathering, sandy and shaly limestones, sandstones and dolomites. 300 feet.	*Distichites* nov. sp. . 250 feet above base. *Monotis salinaria*, Br. . 200 feet above base. *Spirigera dieneri*, Bitt. Base.	Sagenites beds, Diener.	Upper trias.
Coral limestone . . 100 feet.	*Spiriferina griesbachi*, Bitt. *Rhynchonella bambanagensis*, Bitt.	Limestone "with *Sp. griesbachi*," Dien.	
Brown weathering, sandy and shaly limestones, sandstones and shales, and black, splintery limestones. About 500 feet.	*Paratibetites tornquisti*, Mojs. *Juvavites aff. Ehrlichi*, Hau. Upper Half.	Halorites beds, Diener.	
	? *Hauerites n. f. ind.*, Mojs. *Paratibetites aff. tornquisti*, Mojs. Near base.	Hauerites beds, Diener.	
Dolomitic limestone . About 300 feet.		Daonella beds.	
Splintery dark limestones, grey shaly limestones and calcareous shales. From 600 to 700 feet.	*Tropites cf. subbullatus*, Mojs. *Tropites aff. discobullatus*, Mojs. *Clydonautilus griesbachi*, Mojs., etc. About 800 feet above base.		
Grey earthy shales with shaly limestone partings. About 500 feet.	*Spiriferina shalshalensis*, Bitt. *Rhynchonella lankana*, Bitt. About 300 feet above base. *Joannites cymbiformis*, W. *Trachyceras cf. aonoides*, Mojs. Base.		

Hard, dark, splintery limestone, shaly limestones intercalated. About 300 feet.	*Halobia cf. comata*, Bitt. „ *cf. fascigera*, Bitt. Upper part.	Daonella beds.		Upper trias.
	Daonella lommeli, Wiss. Lower part.		Ladinic stage.	Muschelkalk.
Black, shaly limestones, thin-bedded. 160 feet.	*Daonella indica*, Bitt. „ *lommeli*, Wiss. *Gymnites ecki*, Mojs. *Trachyceraladinum*, Mojs. *Proarcestes bicinctar*, Mojs. *Ptychites gerardi*, Blan.			
Grey and black, concretionary limestones, with thin, shaly partings. About 15 feet.	*Ptychites rugifer*, Opp. *Ceratites thuillieri*, Opp.		Upper muschelkalk.	
	Spiriferina stracheyi, Salter, etc.			
	Ceratites subrobustus, Mojs. *Sibirites prahlada*, Dien. *Danubites kansa*, Dien.		Lower muschelkalk.	
Nodular limestone . . About 60 feet.	Very poor in fossils . .			
Grey earthy, concretionary limestones and shales. 40 feet.	*Hedenstræmia mojsisovicsi*, Dien. *Danubites nivalis*, Dien. Near base.		Upper division of lower trias.	Lower trias.
Black limestone and shales. 6 to 7 feet.	*Proptychites ammonoides*, Waag. *Meekoceras nov. sp.* Upper part. *Ophiceras sakuntala*, Dien. Near base.		Otoceras beds.	

Productus shales with *Clyclolobus oldhami*, Waag. Permian.

Abstract *of* Report *on the* Geological structure *of the* sites proposed *for the* Bhavani dam, *by* T. H. HOLLAND, A.R.C.S., F.G.S.

The sites suggested for a dam across the Bhavani valley lie from 4 to 8 miles west of Satyamangalam in the Coimbatore district, and just below the junction of the Moyar with the Bhavani river.

The prevalent rocks in this particular part of the valley are biotite-gneisses of a type generally regarded to be the oldest members of the Archæan group of crystalline rocks. With the biotite-gneisses there occur bands of hornblende schist, quartzites, quartz fuchsite schists, quartz iron ore schists, and members of the charnockite series which have been considerably altered.

The gneisses and schists of the Bhavani valley being situated between two great masses of strong, homogeneous charnockites—the Nilgiris and the Bargur hills—have noticeably suffered severely from the crushing effects of earth movements; but as all such movements ceased in South India early in palæozoic times, when these rocks were deeply buried, the cracks and faults in the gneisses have been completely healed, and their present crushed appearance, due to the preservation of the old scars, is more apparent than real; the gneisses, for all practical purposes, are now as firm as they would have been if they had escaped deformation.

The principal points kept in view whilst examining the proposed sites were—

(1) The distance from the surface of the fresh unweathered rock.

(2) The probable rapidity of alteration on exposure of the fresh rock, to the new conditions near the dam foundations.

(3) The direction and character of the younger joint planes, which would permit percolation of water under pressure.

(4) The coincidence of junction planes between adjoining large formations with the areas of high pressure under the dam, and consequent possibility of differential settlement in the foundations.

(1) The first point had been very thoroughly investigated by the officers of the Public Works Department before the time of my

visit, and the detailed report by Mr. Malet shows the depth of subaërial decomposition at numerous points along each of the proposed sites. It was on account of the great thickness of the soft, weathered rock, that the site A.B.,[1] first selected, was afterwards condemned. Besides the great depths to which the weathering agents have penetrated in the region of the A.B. site, the excavations made to the south of the river cut an intrusion of the peculiar decomposed dunite with magnesite, which is now known in so many isolated patches in South India. Their soft, irregular nature and the readiness with which these rocks (the dunites) lend themselves to hydrous decomposition, render them quite unfit for the foundations of a large dam. There is, therefore, in this discovery an additional reason for abandoning the A.B. site, and I entirely agree with the general opinion of the Engineering officers as to its unsuitability.

(2) With the exception of the dunite referred to in connection with the abandoned A. B. site, there are no rocks in the valley noticeably liable to rapid alteration on exposure to the weather or water. The second consideration needs, therefore, no further discussion.

(3) The display of the old fracture scars and the strongly marked foliation of the biotite-gneisses have given rise to ill-founded suspicions as to their stability. Microscopic sections across the fracture planes show the rocks to be completely re-cemented by crystalline material, and to be just as firm now as if they had never suffered any crushing in the past. Similar remarks apply to the foliation planes, which, at the G. H. site, strike nearly east and west, or at right angles to the alignment of the dam. It has been suggested that such a disposition of the foliation planes parallel to the river bed, and across the line of the dam, will facilitate the percolation of water under the dam; but it should be remembered that though the disposition of the constituent minerals, especially of the mica scales, in bands, permits an easy clearage of isolated fragments along the foliation planes, these planes are perfectly closed up in the rock mass. The *tendency* to easy clearage, due to the thin films of mica principally, is quite consistent with the absence of actual open fissures in the rock mass. The principal channels for percolation would be along the younger joint planes, which occur as frequently

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[1] Three alternative sites known respectively as the A. B., C.D. and G.H. sites were examined, and their positions marked on a geological map accompanying the original report.

across, as along the foliation, and in this particular respect the biotite-gneiss is as sound as most rocks, whilst its composition is unfavourable to any form of solution in water which would tend to widen such joint planes and convert mere cracks into open fissures. I do not consider, therefore, that the direction of the foliation planes can be fairly offered as objection to the G.H. site.

(4) The disposition of the garnetiferous basic rock (garnetiferous amphibolite) forming the small hill along the site C.D., illustrates the fourth point in which the geological features of the site are of importance. It was thought, apparently, that this garnetiferous rock (amphibolite) formed a continuous band along the central portion of the C.D. site; but excavations made at the point where the C.D. line crosses the Bhavani river, reveal the ordinary biotite-gneiss on the left (N.) bank of the river, whilst the amphibolite is found to strike across at a higher point. On following the C.D. line towards C. the amphibolite is again meet with, and then continues as a ridge for over half a mile in the west-north-west direction, that is, parallel to the direction of the similar ridge on the right (S.) bank of the river, but not exactly in line with it; the two ridges are in fact arranged *en echelon*, and the two bands of amphibolite are thus not actually continuous with one another. Either they are parts of a band dislocated by a fault plane near and parallel to the river, or, which is more likely from what we know of the habits of this peculiar rock, the two bands are separate, lens-shaped intrusions into two fissures, parallel to one another, and coincident with the foliation planes in the gneiss.

Usually the lenticular bodies which this rock habitually forms in South India, are stouter and more convex, more definitely lens-shaped in fact. But in the Bhavani valley they have been flattened out by the same earth-movements which have so intensely foliated the associated gneisses, and this fact I did not fully appreciate until I had examined the rocks microscopically. However, the correct geological interpretation of these phenomena is of less importance for the present than the actual fact that at this point, the most critical point in the C.D. site, there is a double geological change, first from amphibolite to biotite-gneiss and, in a short distance, back again to the amphibolite band. Both the amphibolite and the biotite-gneiss would be sufficiently superior to all that will ever be required of them in this respect, that the possibility of differential settlement due to the weight of the dam need scarcely be discussed; but where the water pressure will be so great as it will be at this the deepest point in the reservoir, and where, in fact, all the enemies to its stability will act with maximum effect on the dam, I should consider it advisable, when possible, to avoid building across the junction planes of two dissimilar geological formations.

In the case of the Bhavani project the existence of an alternative site at G.H. offers a means for avoiding this form of danger. Along the G.H. line there is also a change in the geological formation, but the change is between two rock groups which differ merely in structure, not in mineral composition; the differences between a gneissose granite and a biotite-gneiss of the old type in South India, though of theoretical interest to the geologist, are of no importance from the engineering standpoint. But in this instance, too, the change of formation occurs at a point in the G.H. line which is at a higher comparative level than the double, and more serious change, which has just been referred to in connection with the C.D. site.

From the geological standpoint, therefore, I would give a vote in favour of G.H., but it is only fair to state that had C.D. been the only site available I should not consider the change from biotite-gneiss to amphibolite sufficiently important to justify a protest against its selection. At the same time, when another good site is available without any apparent drawbacks, I should, as a matter of principle, decide in favour of the latter.

There is one point on which a brief explanation is due to the members of the committee who favoured the selection of the C.D. site. When going over the ground I noticed that the margins of the amphibolite lenses showed signs of alteration by dynamical metamorphism, but did not fully appreciate the fact that such an alteration had extended to the centre of the mass until the specimens collected had been prepared for microscopic examination. I expected consequently that the rock of the ridges would be highly jointed until Mr. Larminie showed, by excavations made on the Pungur hill, south of the river, that the amphibolite was far more massive than I had expected. The point which I raised in committee, namely, that the jointed rock of the ridges would permit free percolation, must therefore be withdrawn. The amphibolites are, I find, slightly decomposed with formation of carbonate of lime, and they contain also considerable quantities of apatite (phosphate of lime), but the proportions of these minerals do not attain anything near a dangerous degree.

Appendix I.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India, from the 1st April 1899 to the 31st March 1900.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Library.
„ „ „ Museum.
BALTIMORE.—Johns Hopkins University.
„ Maryland Geological Survey.
BERLIN.—Deutsche Geologische Gesellschaft.
„ K. Preuss. Akad. der Wissenschaften.
„ „ Geologische Landesanstalt.
„ „ „ und Bergakademie.
BOLOGNA.—R. Accad. delle Scienze dell' Istituto de Bologna.
BOMBAY.—Bombay branch of the Royal Asiatic Society.
„ „ Natural History Society.
BORDEAUX.—Société Linneenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
„ „ Association for the Advancement of Science.
„ Society of Natural History.
BRESLAU.—Schlesische Gesellschaft für Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australasia.
„ Royal Society of Queensland.
BRISTOL.—Bristol Museum and Reference Library.
BRUSSELS.—Société Royale Belge de Geographie.
BUCHAREST.—Muse.
„ Museului di Geologia si di Palæontologia.
BUDAPEST.—Kön. Ungarische Geologische Gesellschaft.
„ „ „ Anstalt.
CAEN.—Société Linneenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of Bengal.
„ Asiatic Society of Bengal.
„ University of Calcutta.
„ Editor, Indian and Eastern Engineer.
CAMBRIDGE.—Philosophical Society.
„ Woodwardian Museum.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CANADA.—Hamilton Association.

CAPE TOWN-CAPE OF GOOD HOPE.—Geological Commission.
CHICAGO.—Field Columbian Museum.
COPENHAGEN.—Academié Royale des Sciences et des Lettres.
DES MOINES.—Jowa Geological Survey.
DRESDEN.—Naturforschende Gesellschaft.
DUBLIN.—Royal Dublin Society.
„ Royal Irish Academy.
EDINBURGH.—Geological Society.
„ Royal Scottish Geographical Society.
FRANKFURT-AM-MAIN.—Senckenbergische Naturforschende Gesellschaft.
FREIBURG IN BADEN.—Naturforschende Gesellschaft Isis.
GENEVA.—Société de Physique et d' Hist. Nat. de Geneva.
GLASGOW.—Glasgow University.
GÖTTINGEN.—Kōnigl. Gesells. der Wissenschaften.
HALIFAX.—Nova Scotian Institute of Science.
HALLE.—Academia Cæsarea Leop. Carol. Nat. Curiosorum.
„ Naturforschende Gesellschaft.
HELSINGFORS.—Commission Geologique de la Finlande.
„ Société Finlande de Geographie.
INDIANA.—Department of Geology and Natural Resources.
„ Indiana Academy of Science.
JOHANNESBURG.—Geological Society of South Africa.
KÖNIGSBURG.—Kōnig. Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Societe Vandoise des Sciences Naturelles.
LAWRENCE.—Kansas University.
LEIPZIG.—Kōn. Säch. Gesells. der Wissenschaften.
„ Verein für Erdkunde.
LIEGE.—Société Geologique de Belgique.
LILLE.— „ „ du Nord.
LISBON.—Travaux Geologiques du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Association for the Advancement of Science.
„ British Museum (Natural History).
„ Geological Society.
„ „ Survey of the United Kingdom.
„ Iron and Steel Institute.
„ Linnean Society.
„ Royal Geographical Society.
„ „ Institution of Great Britain.
„ „ Society.
„ Society of Arts.
„ Zoological Society.
„ Imperial Institute.
MACON.—L'Institut Colonial di Marseille.
MARSEILLE.—Faculte des Sciences de Marseille.
MADRID.—Sociedad Geografica de Madrid.

MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-supply.
„ Royal Society of Victoria.
MEXICO.—Instituto Geologico de Mexico.
MILAN.—Societa Italiana di Scienze Naturali.
MOSCOW.— „ Imp. des Naturalistes.
MUNICH.—Kōnigl. Bayerische Akad. der Wissenschaften.
NEWCASTLE-UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, American Journal of Science.
NEW YORK.—Academy of Sciences.
„ American Museum of Natural History.
NEUCHATEL.—Société des Sciences Naturelles.
OTTAWA.—Geological and Natural History Survey of Canada.
„ Royal Society of Canada.
PARA.—Museu Paraense de Historia Naturelle Ethnographia.
PARIS.—Department of Mines.
„ Ministere des Travaux Publics.
„ Museum de Histoire Naturelle.
„ Societe de Geographie.
„ „ Geologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PERTH.—Geological Survey, Western Australia.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
„ Wagner Free Institute of Science.
PISA.—Societa Toscana de Scienze Naturali.
PRETORIA.—State Mining Department.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Lincei.
„ „ Comitato Geologico d'Italia.
„ Societa Geologica Italiana.
SAIGON.—Economique d'l' Indo-Chine.
SALEM.—American Association for the Advancement of Science.
„ Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch of the Royal Asiatic Society.
SINGAPORE.—Straits Branch of the Royal Asiatic Society.
STOCKHOLM.—Konig. Svenska Vetenskaps Akademiens.
„ Sveriges Geologiska Undersokning.
ST. PETERSBURG.—Academie Imperialè des Sciences.
„ Comite Geologique.
„ Russ. Kais. Min. Gesellschaft.

SYDNEY.—Australian Museum.
„ Geological Survey of New South Wales.
„ Linnean Society „
„ Royal „ „
„ Department of Mines and Agriculture.
„ Australasian Association for the Advancement of Science.
TOKIO.—College of Science, Imperial University.
„ Deutsche Gesellschaft für Natur-und Völkerkunde.
TOPEKA.—University Geological Survey of Kansas.
TORONTO.—Canadian Institute.
TURIN.—Reale Accad. delle Scienze.
UPSALA.—Geological Institution, University of Upsala.
VENICE.—R. Instituto Veneto di Scienze Lete ed Arti.
VIENNA.—K. Akad. der Wissenschaften.
„ K. K. Geographische Gesellschaft.
„ „ Geologische Reichsanstalt.
„ „ Natur. Historisches Hofmuseum.
WASHINGTON.—Smithsonian Institution.
„ United States Department of Agriculture.
„ „ „ Geological Survey.
„ „ „ National Museum.
„ „ „ „ Academy of Sciences.
WELLINGTON.—New Zealand Institute.
YORK.—Yorkshire Philosophical Society.
ZURICH.—Naturforschende Gesellschaft.

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Appendix II.

The Inspector of Mines in India.

MR. JAMES GRUNDY.

The annual report, which the Inspector of Mines should submit for the Calendar year 1899, has not been sent in up to date, but the Office Records show that during 1899, mines were inspected in Bengal, the Punjab and in Baluchistan. The total number of days on which inspections were actually made, was only 77, whereas 82 days were spent either on office work in camp, or travelling to and from head-quarters.

CALCUTTA:
The 31st March 1900.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

G. I. C. P. O.—No. 3 D. G. Survey.—28-6-1900.—600.

Part 3.—Note on the progress of the gold industry in Wynaad, Nilgiri district. Notes on the representatives of the Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—On the geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

Vol. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Further notices of Siwalik mammalia. Notes on some Siwalik birds. Notes of a tour through Hangrang and Spiti. On a recent mud eruption in Ramri Island (Arakan). On Braunite, with Rhodonite, from near Nagpur, Central Provinces. Palæontological notes from the Satpura coal-basin. Statistics of coal importations into India.

Part 2.—On the Mohpani coal-field. On Pyrolusite with Psilomelane occurring at Gosalpur, Jabalpur district. A geological reconnoissance from the Indus at Kushalgarh to the Kurram at Thal on the Afghan frontier. Further notes on the geology of the Upper Punjab.

Part 3.—On the geological features of the northern part of Madura district, the Pudukota State, and the southern parts of the Tanjore and Trichinopoly districts included within the limits of sheet 80 of the Indian Atlas. Rough notes on the cretaceous fossils from Trichinopoly district, collected in 1877-78. Notes on the genus Sphenophyllum and other Equisetaceæ, with reference to the Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). On Mysorin and Atacamite from the Nellore district. On corundum from the Khasi Hills. On the Joga neighbourhood and old mines on the Nerbudda.

Part 4.—On the 'Attock Slates' and their probable geological position. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Sketch of the geology of North Arcot district. On the continuation of the road section from Murree to Abbottabad.

Vol. XIII, 1880.

Part 1.—Annual report for 1879. Additional notes on the geology of the Upper Godavari basin in the neighbourhood of Sironcha. Geology of Ladak and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Teeth of fossil fishes from Ramri Island and the Punjab. Note on the fossil genera Nöggerathia, Stbg., Nöggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia, and Australia. Notes on fossil plants from Kattywar, Shekh Budin, and Sirgujah. On volcanic foci of eruption in the Konkan.

Part 2.—Geological notes. Palæontological notes on the lower trias of the Himalayas. On the artesian wells at Pondicherry, and the possibility of finding such sources of water-supply at Madras.

Part 3.—The Kumaun lakes. On the discovery of a celt of palæolithic type in the Punjab. Palæontological notes from the Karharbari and South Rewah coal-fields. Further notes on the correlation of the Gondwana flora with other floras. Additional note on the artesian wells at Pondicherry. Salt in Rajputana. Record of gas and mud eruptions on the Arakan coast on 12th March 1879 and in June 1843.

Part 4.—On some pleistocene deposits of the Northern Punjab, and the evidence they afford of an extreme climate during a portion of that period. Useful minerals of the Arvali region. Further notes on the correlation of the Gondwana flora with that of the Australian coal-bearing system. Note on reh or alkali soils and saline well waters. The reh soils of Upper India. Note on the Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts, being fifth notice of the geology of Kashmir and neighbouring territories. Note on some Siwalik carnivora. The Siwalik group of the Sub-Himalayan region. On the South Rewah Gondwana basin. On the ferruginous beds associated with the basaltic rocks of north-eastern Ulster, in relation to Indian laterite. On some Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on the lower trias of the Himalayas.' On some mammalian fossils from Perim Island, in the collection of the Bombay Branch of the Royal Asiatic Society.

Part 2.—The Nahan-Siwalik unconformity in the North-western Himalaya. On some Gondwana vertebrates. On the ossiferous beds of Hundes in Tibet. Notes on mining records, and the mining record office of Great Britain; and the Coal and Metalliferous Mines Acts of 1872 (England). On cobaltite and danaite from the Khetri mines, Rajputana; with some remarks on Jaipurite (Syepoorite). On the occurrence of zinc ore (Smithsonite and Blende) with barytes, in the Karnul district, Madras. Notice of a mud eruption in the island of Cheduba.

Part 3.—Artesian borings in India. On oligoclase granite at Wangtu on the Sutlej, North-west Himalayas. On a fish-palate from the Siwaliks. Palæontological notes from the Hazaribagh and Lohardagga districts. Undescribed fossil carnivora from the Siwalik hills in the collection of the British Museum.

Part 4.—Remarks on the unification of geological nomenclature and cartography. On the geology of the Arvali region, central and eastern. On a specimen of native antimony obtained at Pulo Obin, near Singapore. On Turgite from the neighbourhood of Juggiapett, Kistnah district, and on zinc carbonate from Karnul, Madras. Note on the section from Dalhousie to Pangi *viâ* the Sach Pass. On the South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1.—Annual report for 1881. Geology of North-west Kashmir and Khagan (being sixth notice of geology of Kashmir and neighbouring territories). On some Gondwana labyrinthodonts. On some Siwalik and Jamna mammals. The geology of Dalhousie, North-west Himalaya. On remains of palm leaves from the (tertiary) Murree and Kasauli beds in India. On Iridosmine from the Noa-Dibing river, Upper Assam, and on platinum from Chutia Nagpur. On (1) a copper mine lately opened near Yongri hill, in the Darjiling district; (2) arsenical pyrites in the same neighbourhood; (3) kaolin at Darjiling (being 3rd appendix to a report on the geology and mineral resources of the Darjiling district and the Western Duars). Analyses of coal and fire-clay from the Makum coal-field, Upper Assam. Experiments on the coal of Pind Dadun Khan, Salt-range, with reference to the production of gas, made April 29th, 1881. Report on the proceedings and result of the International Geological Congress of Bologna.

Part 2.—General sketch of the geology of the Travancore State. The Warkilli beds and reported associated deposits at Quilon, in Travancore. Note on some Siwalik and Narbada fossils. On the coal-bearing rocks of the valleys of the Upper Rer and the Mand rivers in Western Chutia Nagpur. On the Pench river coal-field in Chhindwara district, Central Provinces. On borings for coal at Engsein, British Burma. On sapphires recently discovered in the North-west Himalaya. Notice of a recent eruption from one of the mud volcanoes in Cheduba.

Part 3.—Note on the coal of Mach (Much) in the Bolan Pass, and of Sharag or Sharigh on the Harnai route between Sibi and Quetta. New faces observed on crystals of stilbite from the Western Ghâts, Bombay. On the traps of Darang and Mandi in the North-western Himalayas. Further note on the connexion between the Hazara and the Kashmir series. On the Umaria coal-field (South Rewah Gondwana basin). The Daranggiri coal-field, Garo Hills, Assam. On the outcrops of coal in the Myanoung division of the Henzada district.

Part 4.—On a traverse across some gold-fields of Mysore. Record of borings for coal at Beddadanol, Godavari district, in 1874. Note on the supposed occurrence of coal on the Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. On the genus Richthofenia, Kays (Anomia Lawrenciana, Koninck). On the geology of South Travancore. On the geology of Chamba. On the basalts of Bombay.

Part 2.—Synopsis of the fossil vertebrata of India. On the Bijori Labyrinthodont. On a skull of Hippotherium antilopinum. On the iron ores, and subsidiary materials for the manufacture of iron, in the north-eastern part of the Jabalpur district. On laterite and other manganese ore occurring at Gosulpore, Jabalpur district. Further notes on the Umaria coal-field.

Part 3.—On the microscopic structure of some Dalhousie rocks. On the lavas of Aden. On the probable occurrence of Siwalik strata in China and Japan. On the occurrence of Mastodon angustidens in India. On a traverse between Almora and Mussooree made in October 1882. On the cretaceous coal-measures at Borsora, in the Khasia Hills, near Laour, in Sylhet.

Part 4.—Palæontological notes from the Daltonganj and Hutar coal-fields in Chota Nagpur. On the altered basalts of the Dalhousie region in the North-western Himalayas. On the microscopic structure of some Sub-Himalayan rocks of tertiary age. On the geology of Jaunsar and the Lower Himalayas. On a traverse through the Eastern Khasia, Jaintia, and North Cachar Hills. On native lead from Maulmain and chromite from the Andaman Islands. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice.—Irrigation from wells in the North-Western Provinces and Oudh.

VOL. XVII, 1884.

Part 1.—Annual report for 1883. Considerations on the smooth-water anchorages or mud banks of Narrakal and Alleppy on the Travancore coast. Rough notes on Billa Surgam and other caves in the Kurnool district. On the geology of the Chuari and Sihunta parganas of Chamba. On the occurrence of the genus Lyttonia, Waagen, in the Kuling series of Kashmir.

Part 2.—Notes on the earthquake of 31st December 1881. On the microscopic structure of some Himalayan granites and gneissose granites. Report on the Choi coal exploration. On the re-discovery of certain localities for fossils in the Siwalik beds. On some of the mineral resources of the Andaman Islands in the neighbourhood of Port Blair. The intertrappean beds in the Deccan and the Laramie group in western North America.

Part 3.—On the microscopic structure of some Arvali rocks. Section along the Indus from the Peshawar Valley to the Salt-range. On the selection of sites for borings in the Raigarh-Hingir coal-field (first notice). Note on lignite near Raipore, Central Provinces. The Turquoise mines of Nishâpûr, Khorassan. Notice of a further fiery eruption from the Minbyin mud volcano of Cheduba Island, Arakan. Report on the Langrin coal-field, South-west Khasia Hills. Additional notes on the Umaria coal-field.

Part 4.—On the Geology of part of the Gangasulan pargana of British Garhwal. On fragments of slates and schists imbedded in the gneissose granite and granite of the North-west Himalayas. On the geology of the Takht-i-Suleiman. On the smooth-water anchorages of the Travancore coast. On auriferous sands of the Subansiri river, Pondicherry lignite, and Phosphatic rocks at Musuri. Work at the Billa Surgam caves.

VOL. XVIII, 1885.

Part 1.—Annual report for 1884. On the country between the Singareni coal-field and the Kistna river. Geological sketch of the country between the Singareni coal-field and Hyderabad. On coal and limestone in the Doigrung river, near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field-notes.

Part 2.—A fossiliferous series in the Lower Himalaya, Garhwal. On the probable age of the Mandhali series in the Lower Himalaya. On a second species of Siwalik camel (Camelus Antiquus, nobis ex Fale. and Caut. MS.). On the Geology of Chamba. On the probability of obtaining water by means of artesian wells in the plains of Upper India. Further considerations upon artesian sources in the plains of Upper India. On the geology of the Aka Hills. On the alleged tendency of the Arakan mud volcanoes to burst into eruption most frequently during the rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3.—On the Geology of the Andaman Islands. On a third species of Merycopotamus. Some observations on percolation as affected by current. Notice of the Pirthalla and Chandpur meteorites. Report on the oil-wells and coal in the Thayetmyo district, British Burma. On some antimony deposits in the Maulmain district. On the Kashmir earthquake of 30th May 1885. On the Bengal earthquake of 14th July 1885.

Part 4.—Geological work in the Chhattisgarh division of the Central Provinces. On the Bengal earthquake of July 14th, 1885. On the Kashmir earthquake of 30th May 1885. On the results of Mr. H. B. Foote's further excavations in the Billa Surgam caves. On the mineral hitherto known as Nepaulite. Notice of the Sabetmahet meteorite.

VOL. XIX, 1886.

Part 1.—Annual report for 1885. On the International Geological Congress of Berlin. On some Palæozoic Fossils recently collected by Dr. H. Warth, in the Olive group of the Salt-range. On the correlation of the Indian and Australian coal-bearing beds. Afghan and Persian Field notes. On the section from Simla to Wangtu, and on the petrological character of the Amphibolites and Quartz-Diorites of the Sutlej valley.

Part 2.—On the Geology of parts of Bellary and Anantapur districts. Geology of the Upper Dehing basin in the Singpho Hills. On the microscopic characters of some eruptive rocks from the Central Himalayas. Preliminary note on the Mammalia of the Karnul Caves. Memorandum on the prospects of finding coal in Western Rajputana. Note on the Olive Group of the Salt-range. On the discussion regarding the boulder-beds of the Salt-range. On the Gondwana Homotaxis.

Part 3.—Geological sketch of the Vizagapatam district, Madras. Preliminary note on the geology of Northern Jesalmer. On the microscopic structure of some specimens of the Malani rocks of the Arvali region. On the Malanjkhandi copper-ore in the Balaghat district, C. P.

Part 4.—On the occurrence of petroleum in India. On the petroleum exploration at Khátan. Boring exploration in the Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Notice of a fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Notice of the Nammianthal aerolite. Analysis of gold dust from the Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1.—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traverse through Jaunsar-Bawar and Tiri-Garhwal. On the geology of the Garo Hills. On some Indian image-stones. On soundings recently taken off Barren Island and Narcondam. On a character of the Talchir boulder-beds. Analysis of Phosphatic Nodules from the Salt-range, Punjab.

Part 2.—The fossil vertebrata of India. On the Echinoidea of the cretaceous series of the Lower Narbada Valley, with remarks upon their geological age. Field-notes: No. 5—to accompany a geological sketch map of Afghanistan and North-eastern Khorassan. On the microscopic structure of some specimens of the Rajmahal and Deccan traps. On the Dolerite of the Chor. On the identity of the Olive series in the east with the speckled sandstone in the west of the Salt-range in the Punjab.

Part 3.—The retirement of Mr. Medlicott. Notice of J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section I. Preliminary sketch of the geology of Simla and Jutogh. Note on the 'Lalitpur' meteorite.

Part 4.—Note on some points in Himalayan geology. Crystalline and metamorphic rocks of the Lower Himalaya, Garhwal, and Kumaun, Section II. The iron industry of the western portion of the district of Raipur. Notes on Upper Burma. Boring exploration in the Chhattisgarh coal-fields. (Second notice.) Some remarks on Pressure Metamorphism, with reference to the foliation of the Himalayan Gneissose-Granite. A list and index of papers on Himalayan Geology and Microscopic Petrology, published in the preceding volumes of the Records of the Geological Survey of India.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of the Lower Himalaya Garhwal, and Kumaun, Section III. The Birds'-nest or Elephant Island, Mergui Archipelago. Memorandum on the results of an exploration of Jessalmer, with a view to the discovery of coal. A facetted pebble from the boulder bed ('speckled sandstone') of Mount Chel in the Salt-range in the Punjab. Examination of nodular stones obtained by trawling off Colombo.

Part 2.—Award of the Wollaston Gold Medal, Geological Society of London, 1888. The Dharwar System, the chief auriferous rock series in South India. On the Igneous rocks of the districts of Raipur and Balaghat, Central Provinces. On the Sangar Marg and Mehowgale coal-fields, Kashmir.

Part 3.—The Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' The sequence and correlation of the pre-tertiary sedimentary formations of the Simla region of the Lower Himalayas.

Part 4.—On Indian fossil vertebrates. On the geology of the North-west Himalayas. On blown-sand rock sculpture. Re-discovery of Nummulites in Zanskar. On some mica-traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1.—Annual report for 1888. The Dharwar System, the chief auriferous rock-series in South India. (Second notice.) On the Wajra Karur diamonds, and on M. Chaper's alleged discovery of diamonds in pegmatite near that place. On the generic position of the so-called Plesiosaurus Indicus. On flexible sandstone or Itacolumite, with special reference to its nature and mode of occurrence in India, and the cause of its flexibility. On Siwalik and Narbada Chelonia.

Part 2.—Note on Indian Steatite. Distorted pebbles in the Siwalik conglomerate. 'The Carboniferous Glacial Period.' Notes on Dr. W. Waagen's 'Carboniferous Glacial Period.' On the oil-fields of Twingoung and Beme, Burma. The gypsum of the Nehal Nadi, Kumaun. On some of the materials for pottery obtainable in the neighbourhood of Jabalpur and of Umaria.

Part 3.—Abstract report on the coal outcrops in the Sharigh Valley, Baluchistan. On the discovery of Trilobites by Dr. H. Warth in the Neobolus beds of the Salt-range. Geological notes. On the Cherra Poonjee coal-field, in the Khasia Hills. On a Cobaltiferous Matt from Nepál. The President of the Geological Society of London on the International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4.—On the land-tortoises of the Siwaliks. On the pelvis of a ruminant from the Siwaliks. Recent assays from the Sambhar Salt-Lake in Rajputana. The Manganiferous Iron and Manganese Ores of Jabalpur. On some Palagonite-bearing raps of the Rájmahál hills and Deccan. On tin-smelting in the Malay Peninsula. Provisional index of the local distribution of important minerals, miscellaneous minerals, gemstones, and quarry stones in the Indian Empire. Part 1.

Vol. XXIII, 1890.

Part 1.—Annual report for 1889. On the Lakadong coal-fields, Jaintia Hills. On the Pectoral and pelvic girdles and skull of the Indian Dicynodonts. On certain vertebrate remains from the Nagpur district (with description of a fish-skull). Crystalline and metamorphic rocks of the Lower Himalayas, Garhwál and Kumaun, Section IV. On the bivalves of the Olive-group, Salt-range. On the mud-banks of the Travancore coast.

Part 2.—On the most favourable sites for Petroleum explorations in the Harnai district, Baluchistan. The Sapphire Mines of Kashmir. The supposed Matrix of the Diamond at Wajra Karur, Madras. The Sonapet Gold-field. Field Notes from the Shan Hills (Upper Burma). A description of some new species of Syringosphæridæ, with remarks upon their structures, &c.

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Part 4.—Geological sketch of Naini Tal; with some remarks on the natural conditions governing mountain slopes (with a map and plate). Notes on some Fossil Indian Bird Bones. The Darjiling Coal between the Lisu and the Ramthi rivers, explored during season 1890-91 (with a map). The Basic Eruptive Rocks of the Kadapah Area. The Deep Boring at Lucknow. Preliminary Note on the Coal Seam of the Dore Ravine, Hazara (with two plates).

Vol. XXIV, 1891.

Part 1.—Annual report for 1890. On the Geology of the Salt-range of the Punjab, with a re-considered theory of the Origin and Age of the Salt Marl (with five plates). On Veins of Graphite in decomposed Gneiss (Laterite) in Ceylon. Extracts from the Journal of a trip to the Glaciers of the Kabru, Pandim, &c. The Salts of the Sambhar Lake in Rajputana, and of the Saline efflorescence called 'Reh' from Aligarh in the North-Western Provinces. Analysis of Dolomite from the Salt-range, Punjab.

Part 2.—Preliminary Report on the Oil locality near Moghal Kot, in the Sheráni country, Suleiman Hills. On Mineral Oil from the Suleiman Hills. Note on the Geology of the

Lushai Hills. Report on the Coal-fields in the Northern Shan States. Note on the reported Namsèka Ruby-mine in the Mainglôn State. Note on the Tourmaline (Schorle) Mines in the Mainglôn State. Note on a Salt-spring near Bawgyo, Thibaw State.

Part 3.—Boring Exploration *in the* Daltongunj Coal-field, *Palamow* (with a map). *Death of* DR. P. MARTIN DUNCAN. Contributions *to the* study *of the* Pyroxenic varieties *of* Gneiss *and of the* Scapolite-bearing Rocks.

Part 4.—On a Collection of Mammalian Bones from Mongolia. Further note on the Darjiling Coal Exploration. Notes on the Geology and Mineral Resources of Sikkim (with a map). Chemical and Physical notes on Rocks from the Salt-range, Punjab (with two plates).

VOL. XXV, 1892.

Part 1.—Annual report for 1891. Report *on the* Geology *of* Thal Chotiáli *and part of the* Mari country (with a map and 5 plates). Petrological Notes *on the* Boulder-bed *of the* Salt-range, Punjáb, Subrecent *and* Recent Deposits *of the valley plains of* Quetta, Pishin and the Dasht-i-Bedaolat; *with appendices on the* Chamans *of* Quetta; *and the* Artesian water-supply *of* Quetta *and* Pishin (with one plate).

Part 2.—Geology *of the* Saféd Kóh (with 2 plates of sections). Report *on a* Survey *of the* Jherria Coal field (with a map and 3 section plates) (*out of print.*)

Part 3.—*Note on the* Locality *of* Indian Tscheffkinite. Geological Sketch *of the* country north of Bhamo. Preliminary Report *on the* economic resources *of the* Amber *and* Jade mines area *in* Upper Burma. Preliminary Report *on the* Iron-Ores *and* Iron-Industries *of the* Salem District. *On the* Occurrence *of* Riebeckite *in* India. Coal *on the* Great Tenasserim River, Mergui District. Lower Burma.

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VOL. XXVI, 1893.

Part 1.—Annual report for 1892. Notes *on the* Central Himalayas (with map and plate). Note *on the occurrence of* Jadeite *in* Upper Burma (with a map). On *the* occurrence *of* Burmite, *a new* Fossil Resin *from* Upper Burma. Report *on the* Prospecting Operations, Mergui District, 1891-92.

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Part 3.—On the Geology *of the* Sherani Hills (with maps and plates). On Carboniferous Fossils *from* Tenasserim (with 1 plate). *On* a deep Boring *at* Chandernagore. Note *on* Granite *in the districts of* Tavoy *and* Mergui (with a plate).

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VOL. XXVII, 1894.

Part 1.—Annual report for 1893. Report *on the* Bhaganwala Coal-field, Salt-range, Punjab (with map and 2 plates).

Part 2.—Note *on the* Chemical qualities of petroleum *from* Burma. Note *on the* Singareni Coal-field, Hyderabad (Deccan) (with map and 3 plates of sections). Report *on the* Gohna Landslip, Garhwal (with 5 plates and 2 maps).

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VOL. XXVIII, 1895.

Part 1.—Annual report for 1894. *Cretaceous Formation of Pondicherry. Some* early allusions *to* Barren Island; *with a few remarks thereon.* Bibliography *of* Barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks.*

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VOL. XXIX, 1896.

Part 1.—Annual report for 1895. *On the Acicular inclusions in Indian Garnets. On the Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks* (with 1 plate).

Part 2.—Notes on the Ultra-basic rocks *and* derived minerals *of the* Chalk (Magnesite) hills, *and other localities near* Salem, Madras (with 2—6 plates). *Preliminary notes on some* Corundum localities *in the* Salem and Coimbatore districts, Madras (with 7—9 plates). *On the occurrence of* Corundum *and* Kyanite *in the* Manbhum district, Bengal. *On the papers by* DR. KOSSMAT and DR. KURTZ, *and on the ancient Geography of "Gondwana-land." Note from the Geological Survey of India.*

Part 3.—On some Igneous Rocks *from the* Tochi Valley. *Notes from the Geological Survey of India.*

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VOL. XXX, 1897.

Part 1.—Annual Report for 1896. *On* some Norite *and* associated Basic Dykes *and* Lava-flows *in* Southern India (with plates I to II). *The reference of the genus* Vertebraria. *On a* Plant of Glossopteris with part of the rhisome attached, *and on the* structure of Vertebraria (with plates III to V).

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NOTE.—*The Records ceased to be published from the 1st January 1898.*

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